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UNITED STATES DEPARTMENT OF THE INTERIOR
OSCAR L. CHAPMAN, Secretary

BUREAU OF RECLAMATION
MICHAEL W. STRAUS, Commissioner
E. O. LARSON, Regional Director

COLORADO RIVER STORAGE PROJECT

AND

PARTICIPATING PROJECTS

UPPER COLORADO RIVER BASIN

December 1950

MAR 27 1951
YOUNG

Lake City, Utah
Region 4

Project Planning Report
No. 4-8a.81-1

p. 5 of introduction has river name, dam hgt., capacity, power

Co. R. Storage Project-BuRec, 1950

Chapter 3

Total capacity MW Purpose

p. 22 ✓ Cross Mtn. - Yampa R. 295' 5,200,000 60 H, P
& p. 36 of National Park Service letter (same reference) & p. 2 at very end of book
MWS el. 6,090'

p. 25 ✓ Crystal [1] - Gunnison R. 305' 40,000 48 P power
& p. 31 of National Park Service letter (same reference) & p. 13 at very end of book
Blue Mesa Dam of the Curecanti unit would provide storage

p. 27 ✓ Curecanti - Gunnison R. 475' 2,500,000 54 I, H, P
Blue Mesa Dam
& p. 25 of National Park Service letter (same reference) & p. 14 at very end of book

p. 29 ✓ Echo Park - Green R. 525' 6,460,000 200 H, P, S
& p. 37 of National Park Service letter (same reference) & p. 8 at very end of book

p. 33 ✓ Flaming Gorge - Green R. 440' 3,940,000 72 I, H, P, S
Ashley Dam
& p. 34 of National Park Service letter (same reference) & p. 8 at very end of book

p. 35 ✓ Glen Canyon - Colorado R. 580' 26,000,000 800 H, P, S
& p. 7 of National Park Service letter (same reference) & p. 7 at very end of book

p. 38 ✓ Gray Canyon - Green R. 445' 2,000,000 210 H, P, S
& p. 18 of National Park Service letter (same reference) & p. 13 at very end of book

p. 40 ✓ Navajo - San Juan R. 335' ~~[illegible]~~ 1,200,000 30 I, H, P, S
& p. 22 of National Park Service letter (same reference) & p. 2 at very end of book

p. 42 ✓ Split Mtn. [1] - Green R. 245' 335,000 100 P power
Echo Park Dam u/s will provide storage
& p. 37 of National Park Service letter (same reference) & p. 8 at very end of book

p. 45 & ✓ Whitewater - Gunnison R. 255' 280,000 48 I, H, P, S
Bridgewater Dam &
p. 13 of National Park Service letter (same reference) & p. 11 at very end of book

Loads on info. on above projects - Table 2 at back of book

at back of book p. 3, Table 1 →

I = irrigation
H = holdover storage for new irrigation
P = power
S = sediment retention

p. 12 of intro & p. 15 at very end of book
these 2 are authorized
Eden project, Wyoming
35 miles N. of Rock Springs, Wyoming
existing ✓ Big Sandy Dam - Big Sandy Cr. - 40,000 A.F.
" " & p. 16 at very end of book
not existing ✓ Spring Cr. "B" site - Muddy Cr. (trib. of N.F. of Gunnison) - 18,000 A.F.
Paonia project, Colo.
near Paonia, Co.

[1] short term storage only.

#10235482

ID:88081447

TC
425
.C6
C65
1950

CRSP Act
70 stat. 105
4-11-56

ERRATA

COLORADO RIVER STORAGE PROJECT AND PARTICIPATING PROJECTS
PROJECT PLANNING REPORT NO. 4-8a.81-1
DECEMBER 1950

February 21, 1951

Report of the Regional Director:

Page 17, 2nd subtotal in Column 8. Change "27,293,000" to "272,930,000".

Page 21, Paragraph 47(b), 12th line. Change paragraph reference from (h) to (g).

Substantiating Materials:

Page 35, Paragraph 4, First Sentence. Change "curved gravity-type structure" to "arch-type structure".

Drawing No. 588-414-5 following Page 45. Change inlet channel elevation of 4604' shown on the "Profile on Centerline of Outlet Works" to 4640'.

Page 46, Paragraph 3, Last Line. Change 1,200 to 1,500, and 4,730 to 4,756.

Page 59, Table. Under "Annual present and authorized use" change the figure for Wyoming from 329,000 to 239,000.

Page 91, Table. The construction costs allocated to power for Gray Canyon Unit should be $133,090,000 instead of $134,090,000.

Page 94, Column 12. Change the heading from "Column 10 + Col. 11" to "Columns 9 + 10 + 11".

National Park Service:

Page 43, Paragraph 5, Line 6. Change "neraby" to "nearby".

Page 44, Paragraph 2, Line 9. Change "30" to "40".

Page 44, Paragraph 2, Line 10. Change "40" to "30".

p. 13 of intro. ~~TO~~ p. 16 of intro.   Co. R. Storage Project - BuRec 1950

existing   Soldier Cr. Dam and Strawberry Res.

enlargement from 283,000 A.F. to 1,370,000 A.F.

part of Central Utah project, Utah

has it been enlarged?   & p. 16 at very end of book

not existing   Joe's Valley site on Cottonwood Cr. near Castle Dale, Utah

part of Emery County Project

57,000 A.F. & p. 18 at very end of book

not existing   Lemon Dam and Res. on the Florida R., SE of Durango, Co.

23,300 A.F.

Florida project, Co. & p. 18 at very end of book

not existing   Bridger Site on Willow Cr. & p. 20 at very end of book.

offstream res. of 43,000 A.F. (fed by canals)

part of Lyman project, Wyoming

not existing   (Rifle Gap Res.)

Res. of 10,000 A.F. on Rifle Cr. in W.-central CO. near Rifle

part of Silt project & p. 22 at very end of book

not existing   Crawford Res.

Crawford site on Iron Cr. - 14,000 A.F. near Crawford, Co. (west-central Co.)

part of Smith Fork project & p. 22 at very end of book

Co. R. Storage Project - BuRec., 1950

River profiles showing dam locations between
pages 18 and 19 of Chapter 2
& map between pages 21 & 22 - Chapter 2

---

could have been built bigger

stapled to p. 25, Chapter 3

Newspaper articles on Curecanti Res. - Gunnison R.
and Tayler Park Res. enlargement
and Gateview Res. - Lake Fk. of Gunnison R.
Crystal Dam - Gunnison R.
Whitewater - Gunnison R.

---

p. 50 ✓ Desolation Damsite - Green R. near Grey Canyon Damsite

p. 51 ✓ Dewey Damsite - Colorado R. 3 miles below its confluence w/ Dolores R.

p. 51 ✓ Chinle (Bluff) Damsite - San Juan R. - 15 miles d/s of town of Bluff, Utah

p. 51 ✓ Blue Mtn. site - Yampa R. just d/s of confluence of Little Snake R. and Yampa R.

little info.

p. 51 ✓ Goosenecks Damsite - San Juan R.

p. 51 ✓ Slick Horn Damsite - San Juan R.

between Chinle Damsite & u/s bank of the Glen Canyon Res.

In Reply Refer To:
730

UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Washington 25, D.C.

December 22, 1950

The Secretary

of the Interior

Sir:

This is my report on the Colorado River Storage Project and Participating Projects, Upper Colorado River Basin. It is based on the accompanying report of the Regional Director, Bureau of Reclamation, Salt Lake City, Utah, dated December 15, 1950, and is a Department-wide report recommending authorization of the program of all agencies of the Department.

The Departmental report on the inventory of potential developments in the Colorado River Basin, House Document 419, Eightieth Congress, pointed out that, in view of the fact that there is not enough water available in the Colorado River system to permit construction of all of the potential projects and have full expansion of existing and authorized projects, the States of the Colorado River Basin should determine their respective rights to deplete the flow of the Colorado River consistent with the Colorado River Compact. Following issuance of that document, the States of the Upper Colorado River Basin negotiated and formalized a compact called the Upper Colorado River Compact, which has subsequently received the consent of the Congress. Completion of that compact has permitted formulation of at least an initial stage of further development of the Upper Colorado River Basin. The plan proposed and presented in this report has been worked out in close cooperation with representatives of the States of the Upper Colorado River Basin. It would provide flexibility in the basin development and coordination of the interests of the Nation and States of the Upper Colorado River Basin.

It is possible at this time to foresee rather clearly the needs of the Upper Basin in terms of storage requirements for purposes of river regulation, although facilities for utilization of the last drops of water cannot be seen with any clarity. Consequently, the plan is presented for ultimate development in terms of storage, but only for partial development in terms of water utilization. Selection of the plan for ultimate storage is based in general upon securing the needed reservoir capacity for all purposes, while attaining the minimum in evaporation losses, water being prerequisite to the livelihood of the area. As indicated in the recommendations hereafter made, the proposal is such as to permit additions to the plan as other participating projects are investigated

and weighed in light of the over-all water supply. The ultimate storage plan as proposed will permit, in so far as that is practicable, full utilization by the Upper Basin of the 7,500,000 acre-feet of water apportioned to the Upper Basin under the Colorado River Compact. The storage capacity contemplated is designed to assure that the flow of the river at Lee Ferry will not be depleted below 75,000,000 acre-feet in any ten consecutive years. Thus, the Upper Basin may now go forward safely with utilization of its waters and the Lower Basin may be assured that its rights under the compact are protected.

It is not contemplated that all of the ultimate storage plan should be constructed or even authorized at this time. The units will be constructed as required to meet the needs for consumptive use of water and for generation of electrical energy. Authorization is requested for only five of the storage reservoirs.

In addition to permitting the Upper Basin to move forward with utilization of its waters, the Colorado River Storage Project and Participating Projects will provide electrical energy to a large area where it is urgently needed. Flood protection, sediment retention, fish and wildlife conservation, and recreational opportunities will also be provided.

Basically, therefore, there are three fundamental elements in the plan:

(1) Reservoir storage, to conserve and regulate stream flows, and to generate power, which, in turn, produces revenues which assist in repaying the costs of the entire plan;

(2) The Upper Colorado River Account, which will permit uniform power rates and will equate costs of the developments with revenues from all sources; and

(3) Participating irrigation projects, which are made possible by the storage reservoirs, and which, through the Account, will be aided in the return of their reimbursable costs.

Of the ten major dams and reservoirs which will ultimately be required in the main storage plan, five are essential at the outset and are recommended herein. Of the several score of possible irrigation projects, twelve are recommended for authorization or reauthorization at this time, and provision is made for one additional project which is already authorized and under construction to be included under the Account. The Account, which is essential to the plan, is also recommended, and will make the entire system financially feasible.

The Director of the National Park Service has advised that the recreational planning and construction program and the archeological, wildlife, and geological programs, incident to the construction of dams and reservoirs in Dinosaur National Monument, are estimated to cost

$18,354,000. These specific programs should be added to those proposed by the Regional Director and the project cost estimate increased by the above amount.

The Colorado River Storage Project and initial participating projects are engineeringly feasible, economically justified, and financially feasible. Benefits from irrigation and other beneficial water-consuming uses would be realized through construction of dependent projects. The evaluated annual benefits from the storage project ($59,080,000) compare favorably with annual costs assigned to the project ($32,848,000) to produce a benefit-cost ratio of 1.8 to 1.0. The benefits for each of the initial participating projects exceed the costs. Net revenues from the storage project will repay the total construction cost of the storage project within 50 years after the installation of the last generating unit, aid in the return of irrigation costs, make payments to the Upper Colorado River Development Fund hereinafter proposed, and contribute substantial funds to the Treasury. Irrigation revenues from each participating project will pay all of the operation, maintenance, and replacement costs of that project allocated to irrigation, and, in addition, will repay a part of the capital cost of the participating project.

Power payments will be accomplished under contracts which will return the power allocation together with interest at the rate of 3 percent on the unamortized balance. Under such contracts, electrical energy will be furnished at the lowest prices consistent with sound business principles in order to encourage wide-spread use of power throughout the area of service. Irrigation and municipal water payments will be accomplished under contracts with appropriate political subdivisions, preferably districts of the water conservancy type.

In view of the existing national emergency, consideration should be given by those familiar with that situation, to the suitability of the power features of the storage project as they relate to the national defense. The Echo Park and Glen Canyon Dams are so situated in the basin and the status of progress on plans for them is such that either or both could assist in meeting power demands for defense purposes.

My recommendations follow. For all practical purposes they are identical with the recommendations of the Regional Director, but I am also recommending, pursuant to expressions subsequently received from the States, establishment of an investigation fund to assure a continuing and adequate program of investigations in the Upper Basin. This has necessitated minor changes in the Regional Director's recommendations (f) and (h). For clarity and convenience, the entire set of recommendations, as thus revised, is repeated.

It is recommended:

(a) That the plan of development of the water resources of the Upper Colorado River Basin described in this report be approved;

(b) That authority be sought for the Secretary of the Interior, acting pursuant to the Federal reclamation laws (Act of June 17, 1902, 32 Stat. 388, and acts amendatory thereof or supplementary thereto), to construct, operate, and maintain (i) the following units of the Colorado River Storage Project:

Echo Park
Flaming Gorge
Glen Canyon
Navajo
Whitewater

and (ii) the following initial participating projects subject to the terms of paragraph (c) or (g), as appropriate, of these recommendations:

Central Utah (initial phase), Utah
Emery County, Utah
Florida, Colorado
Hammond, New Mexico
LaBarge, Wyoming
Lyman, Wyoming
Pine River Extension, Colorado-New Mexico
Seedskadee, Wyoming
Silt, Colorado
Smith Fork, Colorado
Paonia, Colorado

all as described in the report of the Regional Director but with such modification of, ommissions from, or additions to the works as the Commissioner of Reclamation, with the approval of the Secretary, may find proper;

(c) That, as contemplated in its authorization legislation, the Eden Project, Wyoming, which has previously been authorized and is partially constructed, be included in the plan of development and that the Account hereinafter recommended be charged with that portion of the reimbursable construction cost of the Eden Project which is in excess of the amount specified in the Act of June 28, 1949 (63 Stat. 277); and that the Paonia Project, Colorado, as described in the Regional Director's report, which is also partially constructed, be included in the plan of development and that the Account hereinafter recommended be charged with that portion of the reimbursable costs of the Paonia Project which is in excess of the amount which will be repaid within the period specified in the Act of June 25, 1947 (61 Stat. 181).

(d) That, pursuant to the recommendation of the Commissioner of Indian Affairs, and in order to consolidate the recommendations of the Secretary for dependent projects in the Upper Colorado River Basin, the Shiprock Indian Project be authorized for construction, operation, and maintenance in accordance with laws applicable to the development of irrigation projects on Indian reservations including the provisions of

the Act of July 1, 1932 (47 Stat. 564, 25 U.S.C. 386 A), the benefits of which Act should be extended also to the Indian lands to be served by the Florida and the Pine River Extension projects, provided, however, that the Shiprock project shall receive assistance from the Upper Colorado River Account in the same manner and to the same degree as other participating projects;

(e) That authority be sought for the Secretary, acting pursuant to the laws applicable to the development of National parks, monuments, or recreational areas to the extent to which those laws are not inconsistent with operation of the Colorado River Storage Project units for their primary purposes, to construct, operate, and maintain the recreational facilities proposed in this report;

(f) That, because of interrelationship of the projects in the Upper Colorado River Basin, authority be sought for the Secretary of the Interior to establish an Upper Colorado River Account. The Account should be credited with all power revenues derived from (i) units of the Colorado River Storage Project, and (ii) participating projects located within the natural confines of the Colorado River Basin above Lee Ferry, and with all net power revenues derived from the Central Utah Project (initial phase) subsequent to complete reimbursement of the reimbursable costs of that project. The Account should be charged with all reimbursable construction, operation, maintenance, and replacement costs of the Colorado River Storage Project and participating projects located within the natural confines of the Colorado River Basin above Lee Ferry that are allocated to power purposes or assigned to be returned from power revenues. The Account should be charged with that portion of the irrigation allocation of each participating project's construction cost which is required to be so charged in order to show full reimbursement thereof within 50 years following a suitable development period for that project. The Account should also be charged with payments to the Upper Colorado River Development Fund which is recommended and described in (j) below. Revenues and costs in connection with other undertakings hereafter authorized to be constructed should be included in the Upper Colorado River Account only upon specific authorization by act of Congress;

(g) That the Secretary from time to time recommend to Congress for authorization additional units of the Colorado River Storage Project and additional participating projects and that all participating projects be required to meet the following qualifications:

(1) A project, unit, or phase thereof may be eligible to participate only when and to the extent that all sources of estimated revenue directly available to said project, unit, or phase are insufficient to return its reimbursable costs during its payout period as hereafter specified in (4).

(2) It shall be a project for the use in one or more of the States designated in Article III of the Upper Colorado River Basin Compact of water of the Upper Colorado River system, as that system is defined in such compact, the consumptive use of which is apportioned to those States by that article.

(3) Its total benefits shall exceed its total costs, including, but without limitation, any costs attributable to its direct use of the facilities of the Colorado River Storage Project or any other project, and an appropriate share of the costs of the Colorado River Storage Project.

(4) With anticipated revenues from irrigation, based on the irrigator's ability to pay, it shall be able to pay the operation, maintenance, and replacement costs allocated to irrigation and to pay in a period of 50 years following a suitable development period at least part of the construction cost allocated to irrigation.

(5) There shall be available to aid such participating project, or group of participating projects, an appropriate district, preferably of the water conservancy type, which shall be satisfactory to the Secretary of the Interior, one purpose of which shall be to provide revenues for the project over and above those paid by irrigators, to assist in repayment of construction costs allocated to irrigation.

(6) It shall not require assistance from the Upper Colorado River Account in an amount, which, taking into consideration the prior obligations of the Account and the anticipated revenues from its existing and authorized units, will leave the Account in a deficit position at the end of the pay-out period for the participating project specified in (4) above or will require an increase in the general level of Colorado River Storage Project power rates.

(7) Charges to the Upper Colorado River Account for the benefit of a project commingling water specified in (2) with other water shall not exceed an appropriate share of the construction cost of the works required by that project to use water specified in (2).

(8) Pertinent data sufficient to determine its probable engineering and economic justification and feasibility shall be available.

(h) That the investigations and programs proposed to be undertaken by certain agencies of the Department of the Interior, as summarized in paragraphs 33 through 39 of the Regional Director's report and presented in detail in the appended substantiating materials, be authorized; and that appropriations therefor be nonreimbursable, and that in the case of investigations conducted by the Bureau of Reclamation, except those financed under (j) below, the provisions of the Act of April 19, 1945, should govern;

(i) That there be set up and maintained in the Treasury from the receipts of the Colorado River Storage Project a continuing fund of $1,000,000 to the credit of and subject to expenditure by the Secretary to defray emergency expenses and to insure continuous operation of the project;

(j) That there be set up and maintained in the Treasury from the receipts of the Colorado River Storage Project a special fund, to be known as the Upper Colorado River Development Fund, to which shall be transferred at the end of each fiscal year, beginning with the initial year of commercial power production by the Colorado River Storage Project and the participating projects, 7½ percent of the net power revenues for that year after such net revenues exceed 5 million dollars annually, but not to exceed one million dollars in any one fiscal year, which should be available, upon appropriation (such appropriation to remain available until expended), for expenditure by the Secretary, without prejudice to the use by him for the same purposes of other appropriated moneys, for studies and investigations relating to the development, conservation and utilization of the waters of the Upper Colorado River Basin, all expenditures from said fund to be non-reimbursable and non-returnable under the Federal reclamation laws;

(k) That, as of the close of each fiscal year, beginning with Fiscal Year 1955, the Secretary of the Interior report to the Congress on the status of the Upper Colorado River Basin Account and on the revenues from and costs of constructing, operating, and maintaining the Colorado River Storage Project and participating projects. The Secretary's report should be prepared in such manner as accurately to reflect the Federal investment allocated to power, to irrigation, and to other water supply purposes and the progress of return and repayment thereon, and the estimated rate of progress, year by year, in accomplishing full repayment.

I recommend that you approve and adopt this report as your proposed report on the Colorado River Storage Project and Participating Projects, Upper Colorado River Basin, and that you authorize me in your behalf to transmit copies to the Secretary of the Army and to the

States signatory to the Colorado River Compact for their views and recommendations in accordance with the provisions of Section 1 of the Flood Control Act of 1944 (58 Stat. 887), to the heads of the agencies of the States of Arizona, Wyoming, Utah, Colorado, and New Mexico exercising administration over the wildlife resources of those states for their report and recommendations in accordance with the provisions of the Act of August 14, 1946 (60 Stat. 1080), and to other interested Federal agencies for their views and comments.

Respectfully,

(Sgd) Michael W. Straus

Commissioner

Attachment

Approved: January 26, 1951

(Sgd) Oscar L. Chapman

Secretary of the Interior

UNITED STATES
DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary

BUREAU OF RECLAMATION
Michael W. Straus, Commissioner
E. O. Larson, Regional Director, Region 4

COLORADO RIVER STORAGE PROJECT
AND
PARTICIPATING PROJECTS
UPPER COLORADO RIVER BASIN

December 1950

Region 4
Salt Lake City, Utah

Project Planning Report
No. 4-8a.81-1

CONTENTS

REPORT OF THE REGIONAL DIRECTOR

Page

- Compact and Treaty Obligations 2
- Need for Development 3
- Plan of Development 3
  - Colorado River Storage Project 3
    - Storage System 4
    - Power Development 6
    - Construction Schedule 6
    - Costs 7
    - Benefits 8
    - Benefit-Cost Ratio 8
    - Cost Allocations 8
    - Upper Colorado River Account 9
  - Participating Projects 10
- Investigations of Cooperating Federal Agencies 16
- Conclusions 20
- Recommendations 21

SUBSTANTIATING MATERIALS

- Chapter I General Description 1
  - Physical Features 1
  - Climate 2
  - Settlement 3
    - History 3
    - Population 3
  - Industrial Development 4
    - Local Industry 4
    - Transportation and Power 5
    - Land Uses 6
    - Irrigation 7
    - Other Water Uses 8
    - Undeveloped Resources 8
  - Economic Conditions 9
    - General Conditions 9
    - Community Needs 10
  - Water Compacts and Treaty 10
    - Colorado River Compact 10
    - Mexican Water Treaty 12
    - Upper Colorado River Basin Compact 13
  - Investigations and Reports 15

CONTENTS

Page

Chapter I General Description (Continued)
Previous Investigations 15
Scope of Present Investigations 16
Acknowledgments 16

Chapter II Plan of Development 17
Colorado River Storage Project 17
Project Works 17
Regulatory Storage 18
Irrigation and Other Water-consuming Uses 19
Sediment Control 19
Power Production 20
Participating Projects 20

Chapter III Designs and Estimates 22
Project Works and Costs 22
Cross Mountain Unit 22
Dam and Reservoir 22
Power Features 23
Access 23
Rights-of-way and Relocation 24
Geology 24
Cost Estimates 24
Crystal Unit 25
Dam and Reservoir 25
Power Features 26
Access 26
Rights-of-way and Relocation 26
Geology 26
Cost Estimates 26
Curecanti Unit 27
Dam and Reservoir ..Blue Mesa........ 27
Power Features 28
Access 28
Rights-of-way and Relocation 28
Geology 28
Cost Estimates 29
Echo Park Unit 29
Dam and Reservoir 29
Power Features 30
Geology 31
Access 31
Rights-of-way and Relocation 32
Cost Estimates 32
Flaming Gorge Unit 33
Dam and Reservoir 33
Power Features 33

CONTENTS

Page

Chapter III Designs and Estimates (Continued)

Access 34
Rights-of-way and Relocation 34
Geology 34
Cost Estimates 35
Glen Canyon Unit 35
Dam and Reservoir 35
Power Features 36
Geology 36
Access 37
Rights-of-way and Relocation 37
Cost Estimates 37
Gray Canyon Unit 38
Dam and Reservoir 38
Power Features 38
Access 39
Rights-of-way and Relocation 39
Geology 39
Cost Estimates 39
Navajo Unit 40
Dam and Reservoir 40
Power Features 41
Access 41
Rights-of-way and Relocation 41
Geology 42
Cost Estimates 42
Split Mountain Unit 42
Dam and Reservoir 42
Power Features 43
Access 44
Rights-of-way and Relocation 44
Geology 44
Cost Estimates 44

Now is Dominguez →

Whitewater Unit 45
Dam and Reservoir 45
Power Features 46
Access 46
Rights-of-way and Relocation 46
Geology 47
Cost Estimates 47
Summary 47
Design Data 47
Cost Estimates 49
Construction Schedule 50
Alternative Features 50

CONTENTS

Page

Chapter IV Water Resources 53
  Water Supply 53
    Water Supply Studies 53
    Historical Flow 54
    Past Man-made Depletions 55
    Virgin Flow 55
    Present Modified Flow 57
  Water Available for Future Development 59
    Limitations on Future Development 59
    Evaporation 60
  Storage Requirements--Colorado River Storage Project 61
    Storage Capacity Required for River Regulation 61
    Sediment Storage Requirements 63
    Flood Control Storage Requirements 63
    Storage Requirements for Water Use in Upper Basin 65
  Water Rights 65

Chapter V Power 67
  Present Development 67
    Present Power Resources 67
    Present Energy Requirements 68
    Future Energy Requirements 68
    Additional Power and Energy Needed 69
  Project Power Development 71
    Project Capacities and Capabilities 71
    Utilization and Distribution of Project Power. 73
    Power Revenues 74
    Value of Energy 75
    Conservation of Mineral Fuels 75

Chapter VI Project Operations 77
  Initial Filling of Project Reservoirs 78
  Initial Operation of Completed Project--Year 20 . 78
  Ultimate Project Operation--Year 75 80

Chapter VII Financial Analysis 84
  Annual Benefits and Costs 84
    Annual Benefits 84
      Irrigation Benefits 84
      Fish and Wildlife Benefits 85
      Sediment Retention Benefits 85
      Recreation Benefits 86
      Flood Control Benefits 86
      Mineral Development Benefits 86

CONTENTS

Page

Chapter VII Financial Analysis (continued)
- Power Benefits 86
- Summary 87
- Annual Equivalent Costs 88
  - Cost Assigned to Dependent Projects 88
  - Storage Project Costs 89
- Benefit-Cost Ratio 90
- Cost Allocations 90
  - Allocation of Construction Costs 90
  - Allocation of Operation, Maintenance, and Replacement Costs 92
- Repayment 93
- Upper Colorado River Account 93
  - Participating Projects 95

STATEMENTS AND PROGRAMS OF COOPERATING FEDERAL AGENCIES

Geological Survey 1
- Basic Data Requirements for the Colorado River Storage Project and for Participating and Dependent Projects 1
  - Operation of Stream-gaging Stations Required by Interstate Compacts 1
  - Other Stream Gaging 2
  - Special Erosion and Sedimentation Studies 2
  - Special Water-loss Studies 2
  - Five Reservoirs in the Green River Basin, Wyoming, Utah and Colorado 3
  - Glen Canyon Reservoir and Vicinity, Arizona and Utah 4
  - Navajo Reservoir and Vicinity, New Mexico 5
  - Reservoirs in Gunnison River Basin, Colorado 5
  - Ground Water in the Uinta Basin 5
  - Classification of Federal Lands for Water Development 5
  - Additional Geologic Mapping 6
- Basic Data Requirements for General Basin Development 8

National Park Service 1
- Evaluation of Recreational Benefits of Reservoirs 3
- Upper Colorado River Basin Water Utilization Program and Its Effect on Recreation 3
- Glen Canyon Reservoir 7
  - Description of the Site 8
  - Effect of Glen Canyon Reservoir on National Park Service Areas 9
    - Rainbow Bridge National Monument 9
    - Grand Canyon National Park and National Monument 11
  - Potential Recreational Use 11
  - Recommendations 13

CONTENTS

Page

National Park Service (Continued)
  Whitewater Reservoir 13
    Description of the Site 14
    Potential Recreational Use 16
  Gray Canyon Reservoir 18
    Description of the Site 19
    Potential Recreational Use 20
    Recommendations 21
  Navajo Reservoir 22
    Description of the Site 23
    Potential Recreational Use 23
    Recommendations 24
  Curécanti Reservoir 25
    Description of the Site 28
    Recreational Values 28
    Potential Recreational Use 29
    Effect on Black Canyon of the Gunnison National Monument . 30
    Recommendations 30
  Crystal Reservoir 31
    Description of the Site 32
    Potential Recreational Use 32
    Effect on Black Canyon of the Gunnison National Monument . 33
    Recommendations 34
  Flaming Gorge Reservoir 34
  Cross Mountain Unit 36
  Echo Park and Split Mountain Units 37
    Estimates of Cost 43

Bureau of Land Management 1
  Minerals and Resource Disposal 3
  Land Classification and Resource Inventory 3
  Basic Land Records 5
  Cadastral Surveys 5
  Resource Management, Protection and Rehabilitation 6
    Grazing 6
    Soil and Moisture Conservation 10
    Timber and Woodland Management 12
    Fire Control 12
    Wildlife (Game Management) 13

Bureau of Mines 1
  Introduction 1
  Mineral Production and Extent 3
    Mineral Fuels and Other Hydrocarbons 3
      Coal 3
      Petroleum and Natural Gas 4
      Oil Shale 4
      Bituminous Sandstone and Rare Hydrocarbons 4

CONTENTS

Page

Bureau of Mines (Continued)
  Mineral Production and Extent (Continued)
    Nonferrous Metals 5
    Ferro-alloy Metals 5
    Nonmetallic Minerals 6
  Development and Conservation Programs 6
    Mineral Mining (Except Oil and Gas) 6
      Mining Development and Research 7
      Coal Mining Methods and Reduction of Losses 7
      Ferrous Metals and Alloys 7
      Nonferrous Metals 7
      Nonmetallic Minerals 8
      Mineral Research Unclassified 9
      The Proposed Park Tunnel 9
    Metallurgical Research 10
      Ferrous Metals and Alloys 10
      Nonferrous Metals 12
      Uranium 12
      Unitized Small Smelting Plants 12
      Volatilization Processes 13
      Nonmetallic Minerals 13
    Coal Utilization Investigations 14
    Oil-Shale Development 16
      Resources 16
      Mining 18
      Plant 18
      Retorting 18
      Refining 19
      Plant Location Survey 19
    Petroleum and Natural Gas Research 19
    Mineral Statistics and Economics 20
    Accident Prevention and Health in the Mining Industry 20

Bureau of Indian Affairs........ 1
  Indians and Their Land 1
  Indian Resource Problems 2
  Irrigation 4
  Indian Irrigation Projects in The Upper Basin Navajo Reservation 5
    Shiprock Project 5
    Navajo Animas-La Plata (Potential Project)........ 6
    Navajo Miscellaneous Irrigation Projects (Present and Potential) 6
    Uintah and Ouray (Existing and Potential Extensions) Utah. 7
    Jicarilla Reservation - New Mexico (Existing and Potential) 7
    Southern Ute and Ute Mountain Reservations - Colorado (Existing and Potential) 8
  Soil and Moisture Conservation 8
  Bureau Programs 10

CONTENTS

Page

Fish and Wildlife Service 1
  General 1
  Individual Units and Their Anticipated Effect On Fish and Wildlife Resources 7
    Initial Phase 7
      Glen Canyon Unit 7
      Echo Park and Flaming Gorge Units; Considering Split Mountain and Cross Mountain Units 8
      Whitewater Unit 11
      Navajo Unit 11
    Ultimate Phase 13
      Cross Mountain and Split Mountain 13
      Crystal Reservoir 13
      Gray Canyon 13
      Curecanti Unit 14
  Participating Projects 15
      Eden Project, Wyoming 15
      Paonia Project, Colorado 16
      Central Utah Project 16
      Emery County Project, Utah 18
      Florida Project, Colorado 18
      Hammond Project, New Mexico 19
      Lyman Project, Wyoming 20
      Pine River Project Extension; Colorado and New Mexico 20
      Seedskadee Project, Wyoming 21
      La Barge Project, Wyoming 21
      Silt Project, Rifle Creek, Colorado 22
      Smith Fork Project, Colorado 22
  Suggestions and Recommendations 23

Public Health Service 1
  Construction Phase of Project 1
  Proposed Recreational Development 2
  Stream Pollution Problems 3
  Misquito Control 4

88896

CONTENTS

TABLES

Page

Weather Records at Representative Stations in Upper Drainage Basin . 2
Estimated Costs of Cross Mountain Unit 25
Estimated Costs of Crystal Unit 27
Estimated Costs of Curecanti Unit 29
Estimated Costs of Echo Park Unit 32
Estimated Costs of Flaming Gorge Unit 35
Estimated Costs of Glen Canyon Unit 37
Estimated Costs of Gray Canyon Unit 40
Estimated Costs of Navajo Unit 42
Estimated Costs of Split Mountain Unit 45
Estimated Costs of Whitewater Unit 47
Summarized Data on Units of Colorado River Storage Project 48
Total Project Costs 49
Historical Stream Flows 54
Net Man-Made Depletions in Upper Basin 55
Computation of Virgin Flow At Lee Ferry 56
Average Present Modified Flow at Key Points 57
Annual Present Modified Flow--Colorado River at Lee Ferry 58
Present and Future Consumptive Use, Upper Basin 59
Determination of Active Storage Requirement to Permit Full Utilization of Apportioned Consumptive Use 62
Sediment Encroachment in Project Reservoirs 64
Additional Power and Energy Needed from Bureau of Reclamation Plants in Region 4 for Project Power Market Area 70
Estimated Annual Firm Energy Generation by Project Units 72
Project Operation During Construction and Initial Filling of Reservoirs 79
Initial Operation of Completed Project--Year 20 81
Ultimate Project Operation--Year 75 83
Lowest Cost Single Purpose Regulatory System 89
Allocation of Construction Costs 90
Distribution of Allocated Construction Costs by Project Units 91
Allocation of Annual Operation, Maintenance, and Replacement Costs . 92
Distribution of Allocated Annual Operation, Maintenance, and Replacement Costs by Project Units 92
Financial Operation Study for Examination of Average Rate and Investment Repayment from Power Revenues 94

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Region 4
Post Office Box 360
Salt Lake City 10, Utah

[illegible]

To: Commissioner

From: Regional Director

Subject: Interim Report on Colorado River Storage Project and Participating Projects, Upper Colorado River Basin

1. Transmitted is material for an interim report on the [illegible] of the storage project and their participating projects that would [illegible] to the provisions and purposes of the storage project. The report [illegible] a plan of development and recommends [illegible] participating projects. [illegible] interim reports. [illegible] with the Bureau of Reclamation [illegible] are a part of this report. [illegible] including statements of [illegible]. Supplemental reports cover the details of each participating project.

2. The Colorado River Storage Project would consist of a combination of [illegible] structures [illegible] Upper Colorado River and its principal tributaries. [illegible] development of the Upper Colorado River [illegible]. The project [illegible] would regulate the [illegible] of water to the Lower Basin [illegible] the Colorado River Compact [illegible]. Part of the capacity [illegible] water for direct use by the upper [illegible] Colorado River Storage project [illegible] of the Upper Colorado River Basin. Projects that would [illegible] "participating projects." All projects [illegible] of the Upper Colorado River Basin [illegible] Upper Colorado River system [illegible] storage project for an assured water supply [illegible] "participating" projects.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Region 4
Post Office Box 360
Salt Lake City 10, Utah

December 15, 1950

To: Commissioner

From: Regional Director

Subject: Interim Report on Colorado River Storage Project and Participating Projects, Upper Colorado River Basin

1. This letter is submitted as my interim report on the potential Colorado River Storage project and other reclamation projects that would participate in the benefits and revenues of the storage project. The report outlines a plan of development and recommends an initial construction program. As investigations progress, further recommendations for construction will be made through other interim reports. The plans and programs of Federal agencies cooperating with the Bureau of Reclamation in the storage project investigations are a part of this report. Substantiating materials for the storage project, including statements of cooperating Federal agencies, are appended. Supplemental reports cover the details of each participating project.

2. The Colorado River Storage project would consist of a combination of dams, reservoirs, power plants, and other appurtenant structures on the Upper Colorado River and its principal tributaries. Included as appurtenant structures would be facilities recommended by cooperating Federal agencies for multiple-purpose development of the Upper Colorado River Basin's water resources. The project reservoirs would regulate the flow of the river, assure the delivery of water to the lower basin as required by the Colorado River Compact, and further the use in the upper basin of water apportioned by the compact. Part of the capacity of some of the reservoirs would store water for direct use in the upper basin. Revenues from the sale of project-generated power would be sufficient to pay all reimbursable Colorado River Storage project costs and assist irrigators in payment of costs of other projects that would utilize water of the Upper Colorado River system. Projects that would be so assisted are referred to as "participating projects." All projects authorized subsequent to approval of the Upper Colorado River Basin Compact that would consume water of the Upper Colorado River system are considered to be dependent on the storage project for an assured water supply. Such projects, therefore, are designated "dependent projects."

REPORT OF THE REGIONAL DIRECTOR

3. Authority to make this report and supporting investigations is provided in the Federal reclamation laws (Act of June 17, 1902, 32 Stat. 388, and acts amendatory thereof or supplementary thereto, particularly the Boulder Canyon Project Adjustment Act, 54 Stat. 744).

4. Important contributions to this report and the substantiating materials were made by the Upper Colorado River Compact Commission and States of the Upper Colorado River Basin. Valuable background information on the Colorado River Basin, its present and potential development, its resources, needs, and problems, was obtained from The Colorado River, a Department of the Interior report, dated March 1946, and printed as House Document 419, Eightieth Congress, First Session.

COMPACT AND TREATY OBLIGATIONS

5. In its studies the Bureau of Reclamation has taken full account of agreements affecting the use of Colorado River system water in the upper basin, namely, the Colorado River Compact signed in 1922, the Mexican Water Treaty signed in 1944, and the Upper Colorado River Basin Compact signed in 1948. The Colorado River Compact apportions the use of certain quantities of Colorado River system water to the upper and lower basins and establishes the obligations of Colorado, New Mexico, Utah, and Wyoming, designated "States of the upper division," with respect to deliveries of water at Lee Ferry. Rights of Mexico to the use of water from the Colorado River system are defined in the Mexican Water Treaty. By the Upper Colorado River Basin Compact the use of water apportioned the upper basin is divided among the upper basin States and principles are established to govern deliveries of water to meet the Lee Ferry flow obligations.

6. The upper basin, as defined by the compacts, means "those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system above Lee Ferry." The compact definition of the upper basin is used in the report. For distinction, the natural river basin above Lee Ferry is referred to as the upper drainage basin. Lee Ferry, the dividing point on the Colorado River between the upper and lower basins, is located in northern Arizona. It is defined by the Colorado River Compact as "a point in the main stream of the Colorado River one mile below the mouth of the Paria River."

NEED FOR DEVELOPMENT

7. Now that the upper basin compact has become effective, urgently needed irrigation projects may be undertaken to turn dry land into productive farms and to supplement the meager water supply on some presently irrigated land. An urgent need also exists for water developments to supply municipalities and to permit utilization of the upper basin's vast resources of hydroelectric power, fuels, oils, phosphate, other minerals, and timber. The States of the upper division, however, can realize the use of their apportioned water only when extensive river regulation is provided to assist them in meeting downstream flow obligations established by the Colorado River Compact. With full use of water apportioned the upper basin, an aggregate active reservoir capacity of at least 23,000,000 acre-feet will be required to assure upper division deliveries at Lee Ferry, exclusive of any deliveries required for Mexico. 1/ In addition, capacity must be provided for sediment, power head, and direct use of water in the upper basin.

8. Electric energy requirements are rapidly increasing in the area within and adjacent to the upper basin. In recent years the growing industrialization of the West and the accelerated development of natural resources have taxed existing generating facilities to capacity. Practically every power utility in the market area has plans to increase its generating capacity to meet requirements of the immediate future. By 1980, however, power demands in the area are expected to exceed by far the output of all the installations now scheduled, including installations planned for the Colorado River Storage project. Power demands in the lower basin are even greater than those in the upper basin and are expected to increase at a rapid rate. River regulation and sediment control are needed at an early date to assure maximum utilization of several important power potentialities on the Colorado River below Lee Ferry and above Lake Mead.

PLAN OF DEVELOPMENT

9. The plan of development is presented by a discussion of the Colorado River Storage project, followed by a discussion of participating projects.

Colorado River Storage Project

10. Ten units, each including a dam, reservoir, and appurtenant power facilities, would constitute the Colorado River Storage project.

1/ The extent of storage, if any, required for assistance in the administration of the Mexican Water Treaty cannot be determined at this time. The plan outlined herein does not provide for, nor preclude, storage for this purpose.

The dams would be located above Lee Ferry on the Colorado River and its principal tributaries. Eight of the dams would provide river regulation, namely, Whitewater Dam (Whitewater unit), Cross Mountain Dam (Cross Mountain unit), Blue Mesa Dam (Curecanti unit), Echo Park Dam (Echo Park unit), Ashley Dam (Flaming Gorge unit), Glen Canyon Dam (Glen Canyon unit), Gray Canyon Dam (Gray Canyon unit), and Navajo Dam (Navajo unit). The two additional dams would be built for power head only. One would be the Crystal Dam (Crystal unit) which would benefit from river regulation provided by the upstream Curecanti Reservoir. The other would be the Split Mountain Dam (Split Mountain unit) which would benefit from upstream regulation provided by the Echo Park Reservoir. The various units would be constructed and operated by the Bureau of Reclamation in a manner consistent with agreements affecting the Colorado River. Title to the works would remain in the United States. Information on the ten potential units is summarized in the table on the following page.

11. Investigations to date show that the project as planned would economically provide maximum water utilization and power production with minimum loss of water from evaporation. The project would control sediment, abate floods, facilitate recreational development, and aid in fish and wildlife conservation. As detailed studies progress, some changes in the selected units may be found desirable. So far as practicable adjustments in the plan also will be made from time to time to accommodate supplemental works proposed by interested State and Federal agencies.

Storage System

12. Project reservoirs initially would have a total capacity of 48,555,000 acre-feet, including 37,530,000 acre-feet of active storage and 11,025,000 acre-feet of inactive storage. In a 200-year period at the present rate of erosion, about 20,000,000 acre-feet of capacity would be required for sediment storage--nearly 80 percent of which would be provided at the Glen Canyon site. An estimated 11,589,000 acre-feet of the sediment would settle out in the active storage sections, leaving at the end of 200 years about 25,941,000 acre-feet of active capacity for river regulation and direct use of water in the upper basin. The remaining 8,411,000 acre-feet of sediment would find its way to the dead storage pools, leaving about 2,614,000 acre-feet of inactive capacity for power head, fish propagation, and recreation. The silt deposits would not reduce the original power head. With reduced erosion on the watersheds by improved practices of land management agencies, the period of protection against sediment encroachment would be extended. Future generations could further extend this protection by developing additional upstream sediment storage sites.

13. With full use of water apportioned the upper basin, an active storage capacity of at least 23,000,000 acre-feet would be maintained exclusively for river regulation. The space reserved for river regulation

SUMMARIZED DATA ON COLORADO RIVER STORAGE PROJECT

Project unit	River	Height of dam above river (feet)	Total reservoir capacity (acre-feet)	Active storage capacity (acre-ft)	
				Initially	After 200 years of sediment encroachment	Power instal-lation (kilowatts)
Cross Mountain	Yampa	295	5,200,000	4,200,000	4,030,000	60,000
Crystal 1/	Gunnison	305	40,000	0	0	48,000
Curecanti	Gunnison	475	2,500,000	2,010,000	1,979,000	54,000
Echo Park	Green	525	6,460,000	5,460,000	5,169,000	200,000
Flaming Gorge	Green	440	3,940,000	2,950,000	2,550,000	72,000
Glen Canyon	Colorado	580	26,000,000	20,000,000	10,455,000	800,000
Gray Canyon	Green	445	2,000,000	1,390,000	698,000	210,000
Navajo	San Juan	335	1,200,000	1,050,000	734,000	30,000
Split Mountain 1/	Green	245	335,000	0	0	100,000
Whitewater	Gunnison	255	880,000	470,000	326,000	48,000
Total			48,555,000	37,530,000	25,941,000	1,622,000

1/ Would benefit from upstream storage. Storage at site would be used only for short period power regulation.

would remain nearly full as long as the river flow was sufficient to meet the 10-year Lee Ferry flow obligation of the Colorado River Compact. During periods of critically low flow, water from the regulatory reserves would be released to meet the 10-year Lee Ferry flow obligation. The reserves would be replenished during years of favorable water supply.

14. Some of the regulatory reservoirs may provide direct storage for irrigation and other water-consuming uses in the upper basin. For example, water for the Central Utah project could be provided by a gravity diversion from the Flaming Gorge Reservoir or by pumping from the Echo Park Reservoir. The Whitewater Reservoir by providing replacement water for use on presently irrigated land in western Colorado could permit new irrigation and industrial developments on the west slope of the Continental Divide in Colorado and transmountain diversions to the east slope of the Divide, also in Colorado. Only through the Navajo Reservoir could New Mexico attain full use of its apportioned water. Water from the Navajo Reservoir could directly supply the Shiprock Indian project, the South San Juan project, or by exchange it could benefit possible projects for the exportation of water to the Rio Grande ~~River~~ Basin in Colorado and New Mexico.

15. Initial filling of the project reservoirs may require temporary adjustments in the operation of power facilities on the Colorado River below Lee Ferry. Any adjustments required, however, could be accomplished without prejudice to developments both above and below Lee Ferry. Because of their strategic location, the large Glen Canyon Reservoir and Power Plant would be of particular importance in effecting the proper integration of power and river operations.

Power Development

16. Power plants at the eight regulatory reservoirs and at the Crystal and Split Mountain sites would have a total installed generating capacity of 1,622,000 kilowatts. Power generation would reach a maximum of about 9,000,000,000 kilowatt-hours annually and would decrease to about 6,000,000,000 kilowatt-hours annually with ultimate upstream depletions. Transmission lines would connect the plants with various load centers, either directly or through interconnections with other power systems. Energy requirements in the project service area would be met first from existing and potential local power developments not included in the project. Additional requirements would be met with energy produced by the project facilities.

Construction Schedule

17. The project units would be constructed as required to meet the needs for consumptive use of water and for electric energy. To make certain that project units could be in operation when needed, consideration must be given to cyclic shifts in run-off conditions and the advantages that would be gained by initial filling of the reservoirs while

unused apportioned water is available. The Echo Park, Flaming Gorge, Glen Canyon, Navajo, and Whitewater units are scheduled for initial construction. Construction of the Whitewater, Echo Park, and Glen Canyon units could be undertaken immediately, followed by the Navajo and Flaming Gorge units.

18. The initial five units are favorably situated to supply immediate power market needs in the upper basin and adjacent areas. The Echo Park unit would provide a large amount of power and extensive river regulation with small losses to evaporation. The Echo Park Reservoir would not be seriously impaired by sediment. The Glen Canyon unit could readily meet critical power deficiencies in the lower part of the upper basin and adjacent areas and would permit immediate coordination of power and river operations above and below Lee Ferry. The Glen Canyon Power Plant would provide a source of power which could be used to meet deficiencies which might arise due to use of water for reservoir filling if drought conditions should curtail power generation at other plants. The Whitewater, Flaming Gorge, and Navajo units would facilitate transmission of project energy to Colorado, Wyoming, and New Mexico, respectively. Features of these three units would subsequently assist in the diversion of water for consumptive uses.

Costs

19. The construction cost of the entire Colorado River Storage project is estimated at $1,139,100,000 on the basis of December 1949 prices which are essentially the same as current prices. This estimate includes the cost of dams, power plants, transmission facilities, access facilities, construction camps, rights-of-way, relocation of transportation and communication facilities, investigations, engineering, and overhead. Based on current prices, operation, maintenance, and replacement costs are expected to average about $9,732,100 annually with full project development. A breakdown of costs by project units is shown in the tabulation below.

Project unit	Estimated construction cost	Estimated annual operation, maintenance, and replacement costs
Cross Mountain	$ 51,000,000	$ 414,700
Crystal	37,900,000	325,500
Curecanti	80,400,000	378,100
Echo Park	165,400,000	1,199,200
Flaming Gorge	82,700,000	483,900
Glen Canyon	363,900,000	4,428,600
Gray Canyon	178,400,000	1,239,300
Navajo	63,000,000	251,000
Split Mountain	76,400,000	659,000
Whitewater	40,000,000	352,800
Total	$1,139,100,000	$9,732,100

Benefits

20. The Nation, particularly the States of the Colorado River Basin, would realize substantial benefits from the Colorado River Storage project. Benefit values from power production are estimated at $59,084,000 annually on the basis of average annual equivalents computed at 2.5 percent interest over a 100-year period of operation for each generating unit. Benefits from irrigation and other water-consuming uses in the upper basin would be realized only with the construction of dependent projects. Therefore, benefits from these uses are being evaluated in connection with dependent projects and will be shown in the analysis of each such project. Tangible and intangible benefits that have not yet been evaluated would be realized in the upper basin from recreation, flood control, and fish and wildlife conservation and in the lower basin from sediment retention and river regulation for power production and flood control. These benefits will be evaluated when additional information is provided from further project investigations.

Benefit-Cost Ratio

21. To permit a comparison of project benefits and costs the estimated costs of the Colorado River Storage project were converted to average annual equivalents computed over a 100-year period for each project unit. The annual cost thus computed is $41,994,700. It includes about $32,262,600 for amortization of the net project investment over the period of analysis at 2.5 percent interest and an average of about $9,732,100 for annual operation, maintenance, and replacements over the period of analysis. Allowances were made for interest during construction and the value of salvage at the end of the 100-year period. Inasmuch as benefits from irrigation and other water-consuming uses will be evaluated and shown in the analysis of each dependent project, an appropriate share of the cost of the Colorado River Storage project, totaling $9,671,000 annually, has been assigned to dependent projects. The remainder of the cost, $32,323,700 annually, has been assigned to the storage project. These assignments are for the purpose of benefit-cost analyses.

22. Annual evaluated benefits from the Colorado River Storage project ($59,084,000) would compare with the annual costs assigned the project ($32,323,700) in a ratio of 1.8 to 1.0.

Cost Allocations

23. Costs of the Colorado River Storage project have been tentatively allocated to irrigation and other water-consuming uses and to power as shown in the tabulation on the following page. The allocations were made by averaging the results of the priority-of-use and alternative-justifiable-expenditure methods. No allocations were made to fish and

wildlife conservation, flood control, recreation, sediment retention, or other purposes although in the future such allocations may be found desirable and justified.

Purpose	Construction cost	Annual operation, maintenance, and replacement costs
Irrigation and other water consuming uses	$ 332,950,000	$ 167,700
Power	806,150,000	9,564,400
Total	$1,139,100,000	$9,732,100

Upper Colorado River Account

24. Power revenues would be obtained from the sale of firm energy at an average rate of 5.5 mills a kilowatt-hour and from the sale of secondary energy available in early operations of developments at 3 mills a kilowatt-hour. Such rates would be sufficient to cover, among other things, an interest charge of 3 percent on the unamortized power investment. The indicated rates are based on present expectations as to construction costs. Any appreciable rise in price levels would be reflected in the average rates.

25. All scheduled power revenues from units of the Colorado River Storage project and from participating projects located within the upper drainage basin, and all scheduled net power revenues derived from the Central Utah project (initial phase) subsequent to complete reimbursement of the reimbursable costs of that project, would be credited to an account to be known as the Upper Colorado River Account. The account would be charged with all scheduled payments on the construction, operation, maintenance, and replacement costs of the Colorado River Storage project and participating projects located within the upper drainage basin which costs are allocated to power purposes or assigned to be returned from power revenues. The account would also be charged with scheduled payments on that portion of the construction cost of each participating project allocated to irrigation which is required to be so paid in order to show full reimbursement of the irrigation allocation within 50 years following a suitable development period for that project.

26. Under the suggested construction schedule and plan the total construction cost of the storage project would be repaid 65 years after the first generating unit was placed in operation. The power allocation would be retired within 50 years following installation of the last generating unit.

27. Credits to the Upper Colorado River Account from the revenues of the Colorado River Storage project are expected to exceed charges against the account by the storage project in cumulative amounts shown below.

Year	Net credits from Colorado River Storage project
10	$ 70,600,000
20	196,800,000
30	310,600,000
40	374,200,000
50	382,600,000
60	454,300,000
70	674,900,000

Participating Projects

28. Criteria, listed below, have been established for consideration in the selection of projects to participate in the Upper Colorado River Account. Under these criteria financial assistance would be given only to practicable irrigation projects. Assistance is required by nearly all potential projects in the upper basin since projects already constructed have utilized the least expensive sites and most convenient water supplies.

(a) A project, unit, or phase thereof may be eligible to participate only when and to the extent that all sources of estimated revenue directly available to said project, unit, or phase are insufficient to return its reimbursable costs during its payout period as hereafter specified in (d).

(b) It shall be a project for the use in one or more of the States designated in Article III of the Upper Colorado River Basin Compact, of water of the Upper Colorado River system, as that system is defined in such compact, the consumptive use of which is apportioned to those States by that article.

(c) Its total benefits shall exceed its total costs, including, but without limitation, any costs attributable to its direct use of the facilities of the Colorado River Storage project or any other project, and an appropriate share of the costs of the Colorado River Storage project.

(d) With anticipated revenues from irrigation, based on the irrigators' ability to pay, it shall be able to pay the operation, maintenance, and replacement costs allocated to irrigation, and to pay in a period of 50 years following a suitable development period, at least part of the construction costs allocated to irrigation.

(e) There shall be available to aid such participating project, or group of participating projects, an appropriate district, preferably of the water conservancy type, which shall be satisfactory to the Secretary of the Interior, one purpose of which shall be to provide revenues for the project over and above those paid by irrigators to assist in repayment of construction costs allocated to irrigation.

(f) It shall not require assistance from the Upper Colorado River Account in an amount, which, taking into consideration the prior obligations of the account and the anticipated revenues from its existing and authorized units, will leave the account in a deficit position at the end of the pay-out period for the participating project as specified in (d) above or will require an increase in the general level of Colorado River Storage project power rates.

(g) Charges to the Upper Colorado River Account for the benefit of a project commingling water specified in (b) with other water shall not exceed an appropriate share of the construction cost of the works required by that project to use water specified in (b).

(h) Pertinent data sufficient to determine its probable engineering and economic justification and feasibility shall be available.

29. The criteria outlined are suggested for all participating projects except the Eden project in Wyoming and Paonia project in Colorado, which have previously been authorized. The Act of June 28, 1949 (Public Law 132, Eighty-first Congress, First Session), which authorized the completion of the Eden project, provides: "That construction costs of the irrigation features of the project which are not hereby made reimbursable by the water users shall be set aside in a special account against which net revenues derived from the sale of power generated at the hydroelectric plants of the Colorado River Storage project in the upper basin shall be charged when such plants are constructed." The Paonia project was authorized by the Act of June 25, 1947 (Public Law 117, Eightieth Congress, First Session). Enlargement of the Fire Mountain Canal is in progress under that act. After authorization it was determined that it would not be feasible to construct the Spring Creek Dam at the site described in the project report and that the cost would greatly exceed the estimate. A bill (H.R. 9244, Eighty-first Congress, Second Session) to amend the authorized act is now before Congress. The bill provides that the plan of development be revised and that net revenues derived from the sale of power generated at the hydroelectric plants of the Colorado River Storage project be used to pay reimbursable construction costs that could not be paid by the water users within the repayment period of 68 years specified in the Act of June 25, 1947.

30. Special consideration would be required for projects planned for irrigation of Indian lands. Such projects, however, would be evaluated

by the same criteria as the non-Indian projects in order to determine the extent to which they would be assisted by the Upper Colorado River Account. Any additional assistance required by Indian irrigators would have to be provided by means other than the Upper Colorado River Account.

31. Water available to the upper basin is inadequate for all potential projects. Considerable study will be required of the many potentialities before a complete group of dependent projects may be chosen that have water requirements compatible with the apportionments of the respective States of the upper basin and that are in the best interests of the individual States and the Nation as a whole. Sufficient investigations have been completed, however, to permit selection of a few projects for initial construction and participation in the Upper Colorado River Account. Other participating projects will be selected on the completion of further investigations.

32. Sixteen projects have been recommended cooperatively by the States of the Upper Colorado River Basin for initial participation in the Upper Colorado River Account. Twelve of these projects have been found to meet the criteria set out in paragraph 28. These are described briefly in the following paragraphs and pertinent data from supplemental reports are summarized in tabular form on page 17. Plans for two of the other projects recommended, the Gooseberry project in Utah and the La Plata division of the Animas-La Plata project in Colorado and New Mexico, would have to be revised before these projects would fully meet the criteria outlined. Sufficient investigations have not been made of the Little Snake River project in Wyoming and Colorado, which has also been recommended, to determine whether it would meet the criteria. The Shiprock Indian project also recommended is being investigated by the Bureau of Indian Affairs.

(a) Authorized projects

(1) Eden project, Wyo.--The Big Sandy Dam is being constructed on Big Sandy Creek, 35 miles north of Rock Springs, Wyo., to impound 40,000 acre-feet of water. The reservoir will provide a supplemental water supply for 9,000 acres now irrigated and a full irrigation supply for 11,000 acres of arable dry land. The Means Canal will be constructed to convey reservoir water to the existing Eden Canal and lateral system which will be enlarged and extended.

Construction of the Eden project, approved by the President September 18, 1940, was stopped by order of the War Production Board in December 1942. Completion was authorized by the Act of

June 28, 1949, (Public Law 132, Eighty-first Congress, First Session) and construction is now under way. The authorizing act provides "That of the construction costs of the irrigation features of the project not less than $1,500,000 for the project of twenty thousand irrigable acres, or a proportionate part thereof based on the actual irrigable area..., shall be reimbursable by the water users in not to exceed sixty years..."

(2) Paonia project, Colo.--H. R. 9244 to amend the act authorizing the Paonia project provides for construction of a dam at Spring Creek "B" site on Muddy Creek, a tributary of the North Fork of the Gunnison River. The dam will form a reservoir of 18,000 acre-foot capacity in west-central Colorado near Paonia. The reservoir will provide supplemental water for 14,830 acres now irrigated with only a partial water supply and a full supply for 2,210 acres not heretofore irrigated. Work is nearing completion on the enlargement and extension of the Fire Mountain Canal which will distribute project water. Land served from the extension will include land now irrigated from Minnesota Creek and land on Rogers Mesa now irrigated from Leroux Creek. Leroux Creek water will then be diverted higher upstream and used for irrigation on Redlands Mesa.

(b) Projects Recommended for Authorization

(1) Central Utah project, Utah.--The comprehensive Central Utah project, a large multiple-purpose development, is of such magnitude that it has been planned in two parts--the initial phase, a unified portion that could operate independently, and the ultimate phase. Only the initial phase is included in the group recommended for initial participation in the Upper Colorado River Account.

The initial phase would intercept the flow of streams on the south slope of the Uinta Mountains as far east as Rock Creek and would convey the water westward by gravity flow for use in the Bonneville Basin. Water for replacement and expanded irrigation in the Uinta Basin would be provided by storage on local streams. Several

regulatory reservoirs would be required in both the Bonneville and Uinta Basins, the principal one being the enlarged Strawberry Reservoir on the Strawberry River. By construction of Soldier Creek Dam the capacity of the reservoir would be increased from 283,000 acre-feet to 1,370,000 acre-feet. The initial phase would provide for the irrigation of 29,600 acres of new land and 165,800 acres now irrigated but in need of more water or improved water regulation. It would also provide 48,800 acre-feet of water annually for municipal, industrial, and related uses. It would generate each year approximately 359,100,000 kilowatt-hours of firm energy and 3,400,000 kilowatt-hours of secondary energy.

(2) Emery County project, Utah.--Irrigation water would be furnished 24,080 acres of land under existing canals diverting from Cottonwood Creek and Huntington Creek in east-central Utah near Castle Dale. Supplemental water would be provided for 20,450 acres of the land and a full new supply would be provided for 3,630 acres. The irrigation water would be made available through storage of surplus spring run-off at a 57,000 acre-foot reservoir at the Joes Valley site on Cottonwood Creek. Water for lands in the Huntington Creek area would be conveyed by canal from Cottonwood Creek.

(3) Florida project, Colo.--Lemon Reservoir, with a capacity of 23,300 acre-feet, would be formed by the Lemon Dam on the Florida River in southwestern Colorado, southeast of Durango. This reservoir would regulate the Florida River run-off to provide an irrigation water supply for 18,950 acres, including 12,650 acres now irrigated with only a partial supply and 6,300 acres not now irrigated. Approximately 1,000 acres of the land in the project area are Indian owned. The regulatory storage provided for irrigation would reduce floods which nearly every year cause extensive damage along the river course.

(4) Hammond project, N. Mex.--The Hammond project would divert natural flow of the San Juan River to provide an irrigation supply for 3,670 acres of presently unirrigated land along the south

By the Gap Res.

side of the river near Bloomfield, N. Mex. The water would be diverted from the river by a low diversion dam and conveyed to the project land by a gravity canal. A pumping unit would be installed to lift water 49 feet from the gravity canal to two highline laterals that would serve about 1,110 acres of the project land.

(5) LaBarge project, Wyo.--Unregulated natural flow of the Green River would be diverted for the irrigation of 7,970 acres of land located west of the river between Big Piney and LaBarge in southwestern Wyoming. Only 300 acres of the land are cultivated and partially irrigated at present. The principal construction feature would be a canal 38 miles long, mostly of earth section.

(6) Lyman project, Wyo.--Water would be stored in an offstream reservoir of 43,000 acre-foot capacity at the Bridger site on Willow Creek to furnish supplemental irrigation water for 40,600 acres of land along Blacks Fork near the town of Lyman in southwestern Wyoming. The reservoir would be fed by canals from Blacks Fork and West Fork of Smiths Fork.

(7) Pine River project extension, Colo. and N. Mex.--The extension is planned to enlarge and lengthen distribution works in order that storage water already available in Vallecito Reservoir of the Pine River project might be furnished to some of the arable project land still unirrigated in southwestern Colorado and northwestern New Mexico. The extension would serve 15,150 acres of land, including 1,940 acres administered by the Bureau of Indian Affairs.

(8) Seedskadee project, Wyo.--This project would irrigate 60,720 acres of presently unsettled land located along both sides of the Green River in southwestern Wyoming, about 35 miles east of Kemmerer. The land would be irrigated by gravity diversions from the Green River. Two drops in distribution canals would drive turbines to lift water to higher land. No reservoir storage would be required.

Rifle Gap Res.

(9) Silt project, Colo.--A reservoir of 10,000 acre-foot capacity would be constructed on Rifle Creek in west-central Colorado near Rifle. Most of the reservoir water would be released to water users downstream, replacing part of the natural flow heretofore used. In exchange for the storage water, an equivalent amount of natural flow water would be diverted from East Rifle Creek above the reservoir and conveyed to project land in Dry Elk Valley and on Harvey Mesa. Water would also be conveyed from the reservoir to land under the Davie ditch in Rifle Creek Valley. During the low stages of the reservoir, pumping would be required. In all, 5,000 acres of land would be provided a supplemental water supply and 1,790 acres would be provided a full new supply.

(10) Smith Fork project, Colo.--Surplus run-off of Smith Fork and Iron Creek would be regulated in a reservoir of 14,000 acre-foot capacity at the Crawford site on Iron Creek in west-central Colorado near Crawford. Water from Smith Fork would be diverted to the reservoir by feeder canal. The stored water would be conveyed by canal to land on Grand View Mesa and land adjacent to Cottonwood Creek. Part of the released storage water would replace natural flow on this land, permitting additional diversions of natural flow to land above the reservoir in the Upper Smith Fork Basin. A total of 9,800 acres would be benefited, including 7,670 acres now inadequately irrigated and 2,130 acres of dry land.

INVESTIGATIONS OF COOPERATING FEDERAL AGENCIES

33. The varied and extensive resources of the Upper Colorado River Basin have been under study by several Federal agencies, each charged with specific responsibilities pertaining to the development and protection of natural resources. These studies, however, have not provided all the information required for the detailed planning of complete basin development. Therefore it is necessary that the types of investigations conducted in the past be extended and that the investigations be intensified to provide the detail essential for scheduling the full use of basin natural resources. The continuing studies needed will be conducted by numerous agencies under programs justified by each agency concerned. The results of the studies will be made available to all under cooperative

INITIAL PARTICIPATING PROJECTS--UPPER COLORADO RIVER BASIN
(Preliminary--Subject to Revision)

Project	Irrigable area (acres)			Increased stream depletion[1] (acre-feet annually)	Construction cost			Cost payable from project revenues[3]	Costs payable from Upper Colorado River Account
	New land	Furnished supplemental water	Total		Total[2]	Nonreimbursable	Reimbursable		
Authorized projects									
Eden	11,000	9,000	20,000	17,800	$5,986,000		$5,986,000	$1,500,000	$4,486,000
Paonia	2,210	14,830	17,040	9,000	6,191,000	$147,300	6,043,700	2,415,200	3,628,500
Subtotal	13,210	23,830	37,040	26,800	12,177,000	147,300	12,029,700	3,915,200	8,114,500
Recommended for authorization									
Central Utah (initial phase)	29,600	165,800	195,400	193,400	$222,915,000	7,540,000	215,375,000	167,500,000	47,875,000
Emery County	3,630	20,450	24,080	17,300	8,100,000	133,000	7,967,000	3,370,000	4,597,000
Florida	6,300	12,650	18,950	12,900	6,211,500	363,600	5,847,900	1,057,900[4]	4,790,000
Hammond	3,670		3,670	7,900	1,892,300		1,892,300	238,500	1,653,800
LaBarge	7,670	300	7,970	14,200	1,476,000		1,476,000	416,500	1,059,500
Lyman		40,600	40,600		9,847,000		9,847,000	2,125,000	7,722,000
Pine River Extension	15,150		15,150	28,300	4,088,000		4,088,000	1,638,800[4]	2,449,200
Seedskadee	60,720		60,720	110,400	20,379,000		20,379,000	4,135,000	16,244,000
Silt	1,790	5,000	6,790	5,800	3,055,000	45,200	3,009,800	865,000	2,144,800
Smith Fork	2,130	7,670	9,800	7,500	3,048,000		3,048,000	875,000	2,173,000
Subtotal	130,660	252,470	383,130	397,700	281,011,800	8,081,800	~~27,293,000~~ 272,930,000	182,221,700	90,708,300
Total	143,870	276,300	420,170	424,500	$293,188,800	$8,229,100	$284,959,700	$186,136,900	$98,822,800

[1] Estimated for each project from climatic data for the particular period of water supply study adopted for the preliminary project investigation.

[2] Costs estimated at prices prevailing in December 1949. Do not include nonreimbursable Colorado River Development funds spent for investigations.

[3] Estimated irrigation revenues at average crop prices prevailing in 1939-44 period; Central Utah project revenues also would include revenues from power and municipal use.

[4] Includes $80,000 (Florida project) and $179,000 (Pine River project extension) that would be repaid or adjusted under an extension of the Leavitt Act of July 1, 1932 (47 Stat. 564) authorizing the Secretary of the Interior to adjust reimbursable debts of Indians.

arrangements established by the agencies and by Congress. The Department of the Interior, because of responsibilities delegated to its constituent agencies by Congress, has a major responsibility for resource development in the Upper Colorado River Basin. A fully integrated investigational program by the Department is planned which will include the kind and scope of studies discussed in the following paragraphs.

34. Accurate knowledge of the vital water resources of the basin is obviously indispensable to the consideration of any project involving water control and utilization. To secure additional detailed information required the Geological Survey plans: (1) to add about 20 stream gaging stations to the 80 stations now in operation to facilitate administration of the various interstate compacts and to add about 140 stations to the 200 now in operation to collect the basic data required in the planning of the basin's future water-use projects; (2) to continue the topographic mapping of the entire Upper Colorado River Basin, now only 11 percent complete, with an accelerated program in the areas to be covered by storage project reservoirs; (3) to expand the program for measuring sediment transported by the Colorado River and its principal tributaries in order to confirm estimates of sediment storage capacities required in the project reservoirs; (4) to investigate measures to control erosion at its source; (5) to continue special studies of water losses in the stream channels and adjoining flood overflow areas; (6) to evaluate regional groundwater levels and contributions to stream flow from groundwater sources; (7) to expand the program for analyzing water from all parts of the basin and to maintain a continuing record of water quality; and (8) to complete geologic mapping and inventory of areas which may contain valuable mineral resources.

35. Investigations by the Fish and Wildlife Service provide the basic biological information necessary to evaluate the effect of water-use projects on fish and wildlife resources and to suggest means that may be employed to mitigate the effect of adverse features or operations which are necessary to achieve the primary purposes of the projects. An over-all wildlife study is desired in the Upper Colorado River Basin to determine: (1) the relative importance of developing different portions of the area for migratory birds; (2) the methods and areas that might be developed to relieve the congested big game ranges and increase upland game habitat, especially those to be further restricted by proposed developments; and (3) the possibilities of improving the fisheries by introducing game fish in the reservoirs and by improving streams.

36. The National Park Service has made a general survey of recreational resources of the Upper Colorado River Basin as its part in formulating a comprehensive plan for basin development. Preliminary examinations have been made of each site contemplated for use in the Colorado River Storage project. Detailed studies of each storage project reservoir will be required to plan appropriate facilities for recreational use and

to provide for their management. These detailed studies will include: (1) determination of additional land areas adjacent to the reservoirs that would be necessary for the construction and operation of recreational facilities, (2) surveys and salvage in cooperation with the Smithsonian Institution and local interests of archeological remains endangered by water conservation projects, (3) planning of the specific facilities at each site which can be integrated into the National Park system or managed by State or other Federal agencies, and (4) preparation of estimates of the benefits to result from the planned developments.

37. The Bureau of Land Management is responsible for cadastral surveys on public lands within the Upper Colorado River Basin, maintains records of all land transactions, issues patents to the land, handles applications for all mineral resources, and regulates grazing on the Federal range within the grazing districts and on other lands leased for grazing. The Bureau of Land Management plans to make large-scale studies in erosion control and sediment abatement. It also plans to accelerate the cadastral survey program and land classification and resources inventories.

38. To keep abreast of the increasing National demands for minerals, it is necessary to step up the rate of discovery of new reserves, reduce the cost of mining and handling ores by improvements in techniques, improve methods of recovery and separation, and develop better usage of the minerals and metals. The Bureau of Mines is expanding the search for petroleum and natural gas. It is discovering new reserves of minerals in short supply as well as new ores. Mining research is being done at a demonstration mine at Rifle, Colo., to determine methods and costs of mining oil shale, and a program is being formulated to develop methods of mining thick coal beds to increase extraction as a conservation measure. In the metallurgical field the Bureau of Mines is working closely with the Atomic Energy Commission on the recovery of uranium from complex low-grade ores. Research is being done on the recovery of vanadium and phosphate from low-grade shales and the utilization of phosphate rock. The production of silico-manganese from rhodonite is being studied as a possible method of making available more manganese. Coal utilization studies are being conducted to improve the heat value of coal in order to justify shipping greater distances, particularly to the Pacific Coast area. Studies are being made of the production of synethetic liquid fuel from coal and methods of improving the heat value of coal for utilization as thermal power on a competitive basis to firm up hydroelectric power. Retorting and refining research is being done on oil shale at Rifle, Colo., and Laramie, Wyo., to produce synethetic liquid fuel. The work being done on petroleum and natural gas is directed toward increasing the yield from various fields and thereby increasing reserves.

39. Special responsibilities to the Indians make it necessary that the Bureau of Indian Affairs continue its studies of the utilization of

reservation lands in the upper basin. Further studies will be made to develop Indian lands and to assure the protection of the resources and rights now held by the basin's Indians in order that they may attain an economic independence comparable to that of other citizens of the basin.

CONCLUSIONS

40. The Colorado River Storage project would provide necessary regulatory storage by a combination of reservoirs on the Colorado River and its tributaries above Lee Ferry. All projects that would consume water of the Upper Colorado River system, authorized subsequent to approval of the Upper Colorado River Basin Compact, are considered to be dependent on river regulation for an assured water supply.

41. Reservoirs of the Colorado River Storage project would provide a total storage capacity of about 48,555,000 acre-feet. In 200 years at the present rate of erosion about 20,000,000 acre-feet of the capacity would be occupied by sediment, leaving 25,941,000 acre-feet of active capacity for river regulation and direct use of water in the upper basin and 2,614,000 acre-feet of inactive capacity for creation of power heads, fish and wildlife propagation, recreation, and other purposes.

42. Releases from regulatory reservoirs would produce substantial amounts of electric energy. Power load growth trends indicate that the project power output would readily be absorbed in the power market area.

43. The Colorado River Storage project has engineering feasibility and is economically justified.

44. The initial construction program would include the Echo Park, Flaming Gorge, Glen Canyon, Navajo, and Whitewater units. These would be constructed in an orderly schedule. Construction of the Whitewater, Echo Park, and Glen Canyon units should be started immediately.

45. Revenues from the sale of electric energy generated by units of the Colorado River Storage project would be more than sufficient to pay all reimbursable costs of the project within a period of 50 years after installation of the last generating unit. Project power revenues also would be available to assist irrigators in the payment of construction costs of economically justified and urgently needed participating projects. Financial assistance could best be rendered irrigators through establishment of an Upper Colorado River Account.

46. Development of the Colorado River Storage project and participating projects is essential to the comprehensive development of the upper basin's natural resources. It would provide flexibility in the

basin development and coordination of the interests of the Nation and States of the Upper Colorado River Basin.

RECOMMENDATIONS

47. It is recommended:

(a) That the plan of development of the water resources of the Upper Colorado River Basin described in this report be approved;

(b) That authority be sought for the Secretary of the Interior, acting pursuant to the Federal reclamation laws (Act of June 17, 1902, 32 Stat. 388, and acts amendatory thereof or supplementary thereto), to construct, operate, and maintain (i) the following units of the Colorado River Storage project:

Echo Park
Flaming Gorge
Glen Canyon
Navajo
Whitewater

and (ii) the following initial participating projects subject to the terms of paragraph (~~h~~)g of this recommendation:

Central Utah (initial phase), Utah
Emery County, Utah
Florida, Colo.
Hammond, N. Mex.
LaBarge, Wyo.
Lyman, Wyo.
Pine River extension, Colo.-N. Mex.
Seedskadee, Wyo.
Silt, Colo.
Smith Fork, Colo.

all as described in this report but with such modification of, omissions from, or additions to the works as the Commissioner of Reclamation, with the approval of the Secretary, may find proper;

(c) That the Eden project, Wyo., and the Paonia project, Colo., which have previously been authorized and are partially constructed, be included in the plan of development and, if H. R. 9244, discussed in paragraph 29, is not passed, that the Paonia project be included as a participating project with those described in (b) (ii) above;

(d) That, pursuant to the recommendation of the Commissioner of Indian Affairs, and in order to consolidate the recommendations of the Secretary for dependent projects in the Upper Colorado River Basin, the Shiprock Indian project be authorized for construction, operation, and maintenance in accordance with applicable laws to the development of irrigation projects on Indian reservations including the provisions of the Act of July 1, 1932 (47 Stat. 564, 25 U.S.C. 386 A), provided, however, that this project shall receive assistance from the Upper Colorado River Account in the same manner and to the same degree as other participating projects;

(e) That authority be sought for the Secretary, acting pursuant to the laws applicable to the development of National parks, monuments, or recreational areas to the extent to which those laws are not inconsistent with operation of the Colorado River Storage project units for their primary purposes, to construct, operate, and maintain the recreational facilities proposed in this report;

(f) That, because of interrelationship of the projects in the Upper Colorado River Basin, authority be sought for the Secretary of the Interior to establish an Upper Colorado River Account. The account should be credited with all power revenues derived from (i) units of the Colorado River Storage project, and (ii) participating projects located within the natural confines of the Colorado River Basin above Lee Ferry and with all net power revenues derived from the Central Utah project (initial phase) subsequent to complete reimbursement of the reimbursable costs of that project. The account should be charged with all construction, operation, maintenance, and replacement costs of the Colorado River Storage project and participating projects located within the natural confines of the Colorado River Basin above Lee Ferry that are allocated to power purposes or assigned to be returned from power revenues. The account should also be charged with that portion of the irrigation allocation of each participating project's construction cost which is required to be so charged in order to show full reimbursement thereof within 50 years following a suitable development period for that project. Revenues and costs in connection with other undertakings hereafter authorized to be constructed should be included in the Upper Colorado River Account only upon specific authorization by act of Congress;

(g) That the Secretary from time to time recommend to Congress for authorization additional units of the Colorado River Storage project and additional participating projects and that all participating projects be required to meet the following qualifications:

(1) A project, unit, or phase thereof may be eligible to participate only when and to the extent that all sources of estimated revenue directly available to said project, unit, or phase are insufficient

to return its reimbursable costs during its payout period as hereafter specified in (4).

(2) It shall be a project for the use in one or more of the States designated in Article III of the Upper Colorado River Basin Compact, of water of the Upper Colorado River system, as that system is defined in such compact, the consumptive use of which is apportioned to those States by that article.

(3) Its total benefits shall exceed its total costs, including, but without limitation, any costs attributable to its direct use of the facilities of the Colorado River Storage project or any other project, and an appropriate share of the costs of the Colorado River Storage project.

(4) With anticipated revenues from irrigation, based on the irrigators' ability to pay, it shall be able to pay the operation, maintenance, and replacement costs allocated to irrigation and to pay in a period of 50 years following a suitable development period at least part of the construction cost allocated to irrigation.

(5) There shall be available to aid such participating project, or group of participating projects, an appropriate district, preferably of the water conservancy type, which shall be satisfactory to the Secretary of the Interior, one purpose of which shall be to provide revenues for the project over and above those paid by irrigators, to assist in repayment of construction costs allocated to irrigation.

(6) It shall not require assistance from the Upper Colorado River Account in an amount, which, taking into consideration the prior obligations of the account and the anticipated revenues from its existing and authorized units, will leave the account in a deficit position at the end of the pay-out period for the participating project as specified in (4) above or will require an increase in the general level of Colorado River Storage project power rates.

(7) Charges to the Upper Colorado River Account for the benefit of a project commingling water specified in (2) with other water shall not exceed an appropriate share of the construction cost of the works required by that project to use water specified in (2).

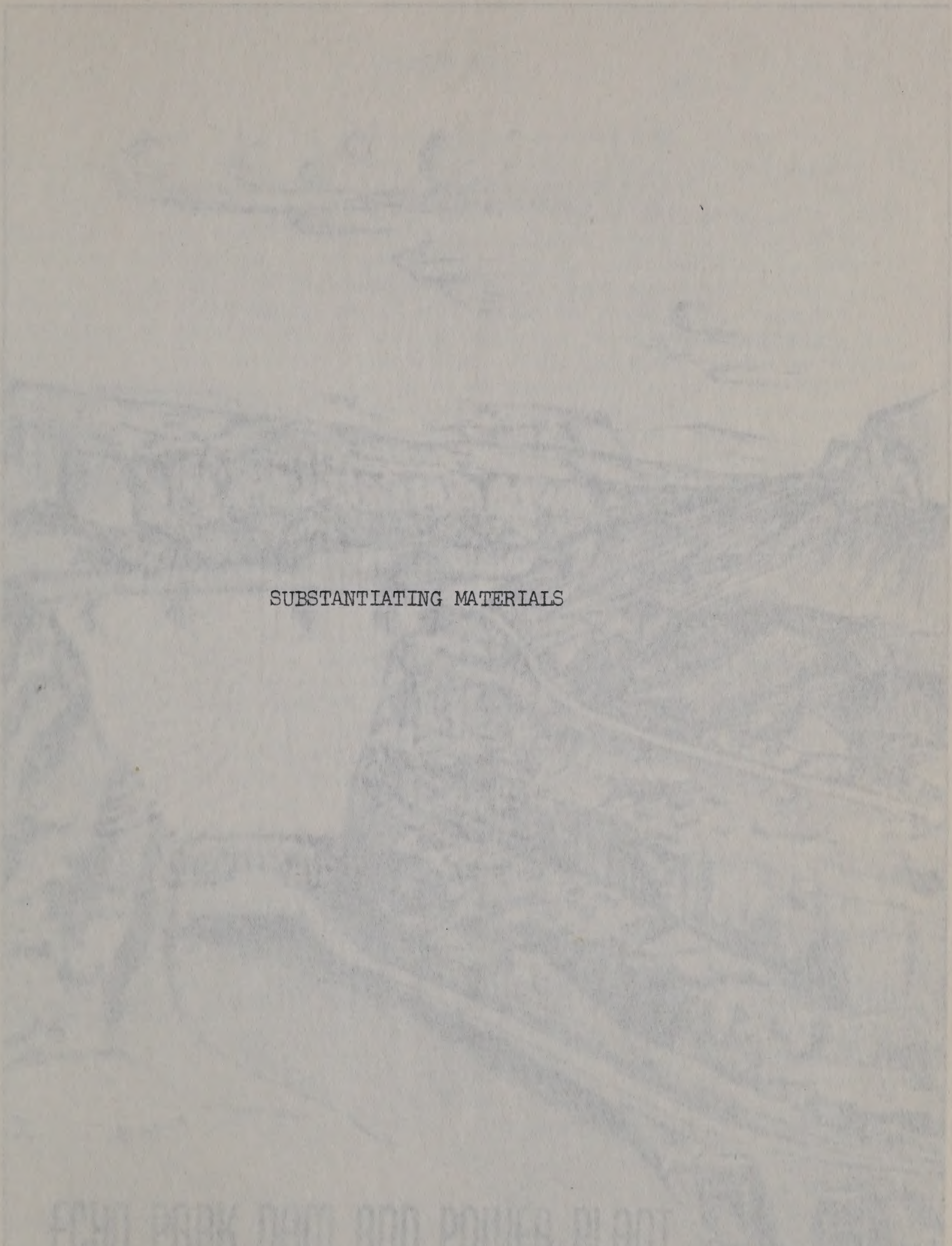
(8) Pertinent data sufficient to determine its probable engineering and economic justification and feasibility shall be available.

(h) That the investigations and programs proposed to be undertaken by certain agencies of the Department of the Interior, as summarized in paragraphs 33 through 39 of this report and presented in detail in the appended substantiating materials, be authorized; and that appropriations therefor be nonreimbursable, and that in the case of investigations conducted by the Bureau of Reclamation the provisions of the Act of April 19, 1945, should govern;

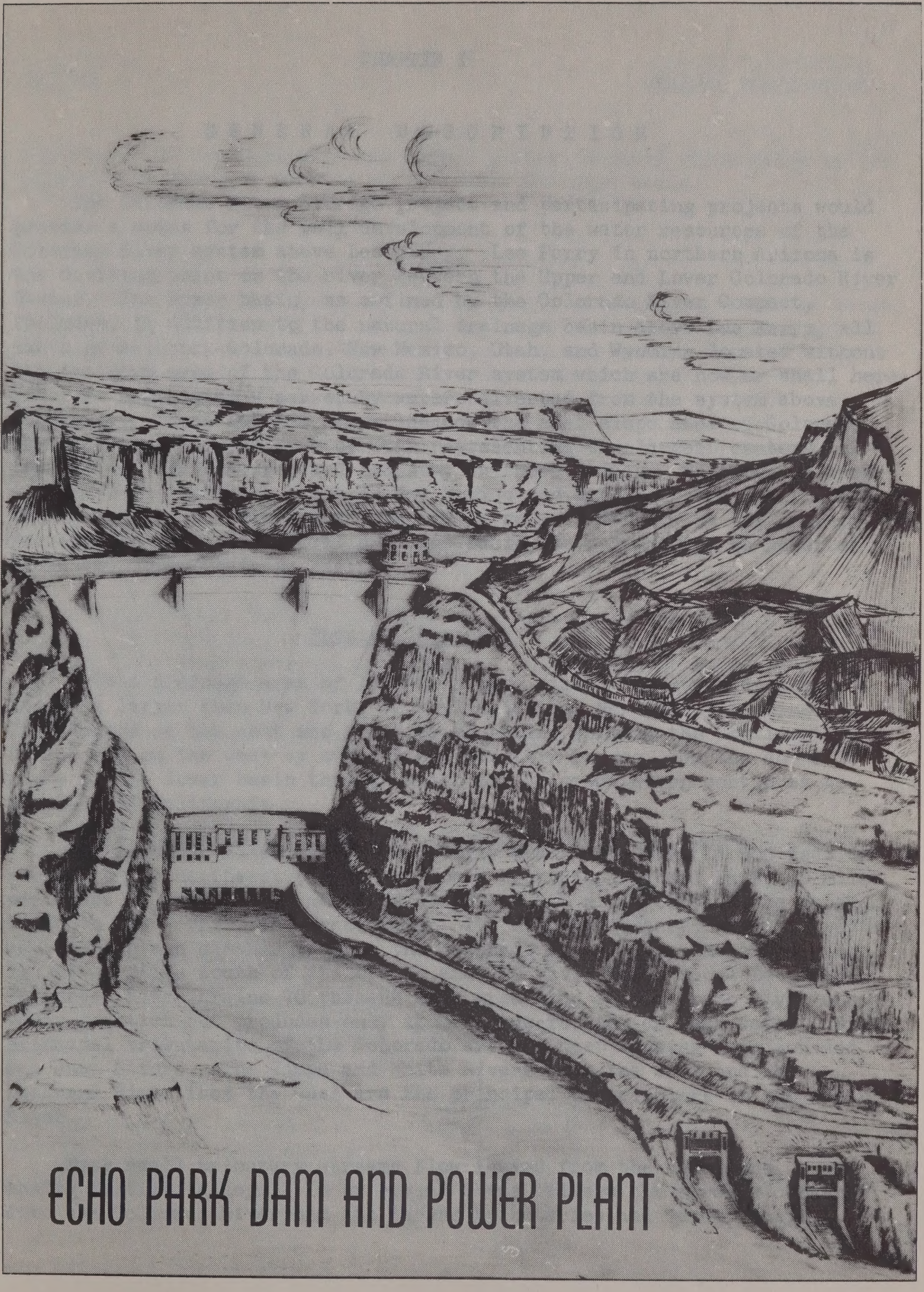
(i) That there be set up and maintained in the Treasury from the receipts of the Colorado River Storage project a continuing fund of $1,000,000 to the credit of and subject to expenditure by the Secretary to defray emergency expenses and to insure continuous operation of the project;

(j) That as of the close of each fiscal year, beginning with Fiscal Year 1955, the Secretary of the Interior report to the Congress on the status of the Upper Colorado River Basin Account and on the revenues from and costs of constructing, operating, and maintaining the Colorado River Storage project and participating projects. The Secretary's report should be prepared in such manner as accurately to reflect the Federal investment allocated to power, to irrigation, and to other water supply purposes and the progress of return and repayment thereon, and the estimated rate of progress, year by year, in accomplishing full repayment.

E. O. Larson


ECHO PARK DAM AND POWER PLANT

SUBSTANTIATING MATERIALS



ECHO PARK DAM AND POWER PLANT

CHAPTER I

GENERAL DESCRIPTION

The Colorado River Storage project and participating projects would provide a means for the full development of the water resources of the Colorado River system above Lee Ferry. Lee Ferry in northern Arizona is the dividing point on the river between the Upper and Lower Colorado River Basins. The upper basin, as defined by the Colorado River Compact, includes, in addition to the natural drainage basin above Lee Ferry, all parts of Arizona, Colorado, New Mexico, Utah, and Wyoming located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system above Lee Ferry. These outside areas include the east slope area of Colorado and the Wasatch front area of Utah representing the largest centers of population, agriculture, and industry in these States. The outside areas also include important areas in New Mexico and Wyoming. The upper basin, as referred to in this report, is the large area defined by the compact. For distinction, the natural drainage basin above Lee Ferry is referred to as the upper drainage basin.

Physical Features

With a drainage area of 110,000 square miles, the upper drainage basin is larger than New York, Pennsylvania, and New Jersey combined. It is bound on the east and north by mountains forming the Continental Divide and on the west by other Rocky Mountain ranges. On the south it opens to the lower basin through which the Colorado River continues to the Gulf of California.

The Colorado River rises among lofty peaks more than 14,000 feet in height in the northwest portion of Rocky Mountain National Park, 70 miles northwest of Denver. It meanders southwest 640 miles through the upper basin to Lee Ferry. The Green River, its major tributary, rises in western Wyoming and discharges into the Colorado River in southeastern Utah, 730 river miles south of its origin and 220 river miles above Lee Ferry. The Green River drains 70 percent more area than the Colorado River above their junction but produces only about three-fourths as much water. Other principal tributaries of the Colorado are the west-flowing Gunnison and San Juan Rivers. The Yampa and White Rivers from the east and the Duchesne River from the west are the principal contributors to the Green River.

Many small tributary streams flow inward from the mountains, traversing fertile valleys. In or beyond these valleys the streams converge into the Colorado River and its larger tributaries and become deeply

entrenched in the expansive and rugged plateau country which makes up the central and southern portion of the upper drainage basin.

Climate

A wide range of climate in various parts of the upper drainage basin is caused by differences in altitude and latitude and to a lesser extent by topographic features. Extremes of temperatures range from 52° below zero at Kendall, Wyo., to 109° above zero at Shiprock, N. Mex. The northern portion of the drainage basin is characterized by short, warm summers and long, cold winters. In the southern portion summers are longer and winters are moderate at low altitudes but colder temperatures prevail in the mountains. A peculiar climatic condition exists in parts of western Colorado where topographic features create an air drainage in localized sections along the foothills. This condition mitigates frost damage and favors the growing of such fruits as peaches, pears, apricots, cherries, and berries.

Precipitation increases with altitude, being heaviest in the high eastern and northern portions of the basin. Most precipitation falls in the form of winter snows and spring rains. The higher mountain peaks are snow capped most of the year.

Weather records for representative stations are summarized in the following table.

WEATHER RECORDS AT REPRESENTATIVE STATIONS IN UPPER DRAINAGE BASIN

	Kendall, Wyo.	Vernal, Utah	Gunnison, Colo.	Grand Junction, Colo.	Shiprock, N.Mex.
Elevation above sea level, feet	7,600	5,266	7,683	4,587	4,950
Number of years of record	28	52	59	60	20
Mean annual temperature, degrees	33.3	45	37	52	53.2
Minimum temperature, degrees	-52	-38	-47	-21	-18
Maximum temperature, degrees	103	103	105	105	109
Average annual precipitation, inches	17.3	8.8	10.2	8.9	8.0
Average snowfall, inches	138.6	26.0	50.2		9.9
Average number of days between killing frosts	53	118	95	223	157

Settlement

History

Settlement of the upper drainage basin began in 1854 when Mormon pioneers established Old Fort Supply in Wyoming on their immigrant trail and diverted water from Blacks Fork onto adjacent land. Breckenridge, Colo., on the basin's eastern rim was settled in 1859 by miners and prospectors pushing over the mountains from older mining districts on the eastern slope of the Continental Divide. Within the next decade other mining camps were established nearby. Unsuccessful miners turned to farming and supplied agricultural products to the mining communities. Settlement grew downward from the mountains to the valleys, the advance being slowed somewhat by conflicts with the Indians who occupied the territory. Grand Junction, Colo., now the largest community in the upper drainage basin, was not settled until 1882.

The greater part of the Uinta Basin in northeastern Utah was established as an Indian reservation in 1861 and lands unoccupied by Indians were not opened to settlement until 1905. Most lands of agricultural importance in the San Juan River Basin in Colorado, New Mexico, and Arizona were once included in Indian reservations, and substantial areas are still under Indian control. The United States, however, purchased 3 million acres from the Indians in 1873 and in 1899 opened to white settlers reservation land unoccupied by Indians. Some Indian allotted lands have been purchased by individual whites.

Population

The Upper Colorado River Drainage Basin is sparsely populated. The 1940 census showed 286,450 people in the basin. The average density was 2.6 persons a square mile compared with a National average of 44.2 persons a square mile. The 1940 population was a little more than double that of 1900. The growth over the 40-year period was slightly faster than the National average but far slower than the average for the western States. A substantial increase in population is expected to be shown by the 1950 census primarily because of the accelerated development of mineral resources in the last 10 years. The population of the upper drainage basin by decades is shown below.

Year	Population
1900	131,500
1910	191,930
1920	223,150
1930	224,300
1940	286,450

About 92 percent of the people in the upper drainage basin are white. Of the non-whites, Indians are in greatest number. In 1940 about 20,000 Indians lived in the San Juan River Basin and about 1,200 in the Uinta Basin.

The six largest towns in the upper drainage basin with their 1940 and 1950 populations are listed below.

Town	Population 1940	1950
Grand Junction, Colo.	12,470	14,454
Rock Springs, Wyo.	9,827	10,785
Durango, Colo.	5,887	7,437
Price, Utah	5,214	5,999
Montrose, Colo.	4,764	4,848
Delta, Colo.	3,717	4,077

The growth of Grand Junction, Montrose, and Delta is largely attributable to Federal reclamation projects constructed early in the century. Federal reclamation projects also have been important factors in the economy of Durango and Price. Durango, Price, and Rock Springs, however, depend primarily on mining and railroading. Farmington, N. Mex., is an important agricultural center and is rapidly developing as an oil and gas producer.

Immediately east of the Upper Colorado River drainage basin is the most densely populated part of Colorado including Denver, Pueblo, Colorado Springs, Fort Collins, and other cities and towns. Just west of the basin are Ogden, Salt Lake City, Provo, and other communities containing Utah's heaviest concentrations of population. Important population centers such as Rawlins, Laramie, and Cheyenne, Wyo., and Santa Fe, Los Alamos, and Albuquerque, N. Mex., also lie adjacent to the Upper Colorado River Basin.

Industrial Development

Local Industry

Agriculture, particularly livestock raising, and mining are the principal industries of the upper drainage basin. Oil refining, lumbering, transportation, trade, recreation, and construction are of lesser but growing importance.

The processing of agricultural products on a small scale is practically the only manufacturing undertaken in the upper drainage basin. Three factories process fruits and vegetables and two beet sugar factories are

in operation. In several farming areas small grain mills produce flour and other grain products, largely for local use. A few small creameries and cheese plants also operate in the area.

Industrial development of minerals and exploration for new minerals have been retarded by the remoteness of large portions of the drainage basin from industrial and transportation centers. The basin, however, provides many raw materials for important industrial areas centered at Denver, Pueblo, Provo, and Salt Lake City.

Large coal fields in the upper drainage basin are being extensively worked. About 15 million tons of coal were mined in 1943. Oil and gas are produced in the San Juan River Basin, the Uinta Basin, and in northwestern Colorado. Several producing fields have been developed recently, and widespread exploration is continuing. Pilot plants are being operated to determine the best methods of extracting oil from shale. These plants portend an important industry for the future.

The largest industrial centers of the Intermountain West are located in Colorado and Utah, immediately east and west of the Upper Colorado River Drainage Basin. The greater part of these industrial areas may utilize water from the Upper Colorado River system since by compact definition these areas are potentially a part of the upper basin. In both of these adjacent areas fertile agricultural lands support a diversified agriculture with livestock raising predominating. Agriculture in turn supports various manufacturing establishments engaged in the processing of food and kindred products. Both areas have important meat packing and beet sugar refining plants. Other industries closely related to agriculture, such as milling and baking and the processing of dairy products, eggs, poultry, fruits, and vegetables, are prominent. The mining, milling, and refining of metals and the manufacture of steel are basic industries in both Colorado and Utah. Oil refineries in each State are sustained in large measure by crude oil from the Upper Colorado River Drainage Basin. A great variety of products is manufactured for world trade. During World War II the industrial areas in both Colorado and Utah were developed on a broad scale for the manufacture, repair, processing, and storage of military supplies and equipment.

Transportation and Power

The Union Pacific Railroad crosses the upper drainage basin in Wyoming. Farther south in Colorado and Utah the basin is crossed by the Denver and Rio Grande Western Railroad which has shipping points at Price and Greenriver, Utah, and at various places along the Colorado, Gunnison, and Uncompahgre Rivers in Colorado. A narrow-gage branch of the Denver and Rio Grande Western Railroad connects with the standard-gage line at Alamosa, Colo., extends west to Durango, Colo., and then continues south to Farmington, N. Mex. A branch of the Denver and Rio Grande Western Railroad enters the upper drainage basin from the east and terminates at Craig, Colo.

Pinedale, Wyo., in the extreme north of the drainage basin must transport its livestock and crops 102 miles to Rock Springs, the nearest railroad point. Closest rail centers to Vernal, Utah, are Helper, Utah, 105 miles distant, and Craig, Colo., 123 miles distant. Other important areas in southern and eastern Utah and in the Dolores River Basin in Colorado are many miles from rail connections.

United States Highways Nos. 6, 30, 40, 50, and 160 extend east and west across the drainage basin. North-south Highways Nos. 187 and 189 serve the Wyoming portion of the basin and Highways Nos. 160 and 550 extend from Crescent Junction, Utah, and Grand Junction, Colo., respectively, into the San Juan River Basin. Many Federal, State, and local highways are interconnected. Good roads have fostered the trucking systems that serve the area. A few unimproved roads traverse the barren and badland regions.

Electric generating installations in the Upper Colorado River Drainage Basin have a total capacity of approximately 120,000 kilowatts. About 9,000 kilowatts is driven by internal combustion engines and the remainder is divided almost equally between hydroelectric and steam-electric plants. About two-thirds of the total capacity is in Colorado where hydroelectric installations predominate. About one-fourth of the basin capacity is in the Wyoming area, mostly at steam-electric plants owned by two coal mining companies. In the Utah and New Mexico portions of the basin, internal combustion installations provide the largest part of the generating capacity Power requirements in the coal mining areas near Price, Utah, are supplied with power transmitted into the basin from the west. Small internal combustion installations provide most of the energy used in the New Mexico area.

Land Uses

Of the land in the upper drainage basin only about 22 percent is privately owned. The remaining 78 percent is owned by either the county, State, or Federal Government or by Indians. The approximate pattern of land use is shown below.

	Acres	Percent of total area
Irrigated land	1,385,000	2.0
Cultivated without irrigation	272,000	0.4
Grazing land:		
Publicly owned	29,221,000	41.5
Privately owned	8,775,000	12.5
State and county owned	2,860,000	4.1
Indian reservations	8,775,000	12.5
National forests	13,378,000	19.0
National parks and monuments	586,300	0.8
Miscellaneous areas	5,077,700	7.2
Total	70,330,000	100.0

About 70 percent of the total land area is classed as grazing land in the tabulation. Grazing is also extensive on National forest lands and on other areas so that much more than 70 percent of the total area is actually grazed. The 1940 United States Census reported 285,000 acres of irrigated land used as pasture.

The better grazing lands are in the high stream valleys and on the mountains and foothills. These lands are used for summer grazing of cattle and sheep, and the scanty vegetation in the lower desert areas provides winter range for sheep.

Crop land, both irrigated and dry-farmed, comprised only 2.4 percent of the total acreage in 1939 and only 2.0 percent was actually cropped.

Farming without irrigation is generally unsuccessful in the upper drainage basin because of the uncertain rainfall. It is practiced, however, to some extent in the Yampa and White River Basins. Favorable climatic conditions in the past few years together with high prices have encouraged expansion of dry farming in the Dry Side area of the LaPlata River Basin and on the upland mesa between Cortez, Colo., and Monticello, Utah. In general, at altitudes where rainfall is sufficient during the summer to grow crops without irrigation, the season is too short for crops to mature.

Irrigation

Numerous tributary streams in the upper drainage basin have been diverted to irrigate meadows in mountain valleys and more general farm lands in broader valleys at the base of the mountains. About 1,385,000 acres are now irrigated in the upper basin distributed among the States as follows: Arizona, 10,000 acres; Colorado, 791,000 acres; New Mexico, 43,000 acres; Utah 304,000 acres; and Wyoming, 237,000 acres.

Many of the larger irrigation projects have been undertaken with Federal assistance. The Bureau of Reclamation has constructed or is constructing nine projects to utilize water in the upper basin. The increase in areas irrigated by reclamation projects is illustrated below.

Year	Acres irrigated in upper drainage basin
1910	24,000
1920	74,500
1930	81,200
1940	166,600
1946	209,500

About 200,000 acre-feet of water is exported annually from the upper drainage basin for use in adjacent areas where local water supplies are inadequate. The exportations are made largely through five Bureau of Reclamation projects and the city of Denver systems that convey water to adjacent areas to the east, southeast, and west. When projects now authorized are fully constructed, and when existing systems are expanded to utilize their full water rights, a total of about 680,000 acre-feet will be exported annually.

Other Water Uses

Because of the sparse settlement in the upper drainage basin, present domestic and municipal water requirements are relatively small and are usually supplied from local sources. As a rule water for the livestock which graze throughout the area is provided directly from natural springs and streams. Industrial requirements for water are presently insignificant but could become important, particularly in the processing of oil shale, coal, and wood pulp. The small beginning made in the development of hydroelectric power resources is almost wholly in Colorado. Mountain streams throughout the basin provide excellent trout fishing, and streams, lakes, and reservoirs are recreational attractions.

Local flood damage frequently occurs along tributary streams, but the lower stretches of the river and its major tributaries are confined in deep and barren canyons where floods can do no damage. From these lower regions, however, and particularly from the San Juan Basin, enormous quantities of sediment enter the river. The sediment is now carried to Lake Mead in the lower basin, constantly decreasing the storage capacity of this reservoir formed by Hoover Dam. The tremendous capacity of Lake Mead could retain the sediment for many years but potential lower basin reservoirs with smaller capacities at Bridge Canyon and Marble Canyon upstream from Lake Mead would soon be filled unless the sediment is controlled by other upstream structures.

Undeveloped Resources

Mineral resources of the Upper Colorado River Drainage Basin are varied and extensive. Reserves of bituminous and sub-bituminous coal are roughly estimated at 400 billion tons or about a third of all the known coal deposits in the United States and one-sixth of those in the world. Some of this coal is below present mineable depths, but mineable reserves alone equal nearly one-fourth of the country's total deposits.

Oil and gas have been discovered in more than 40 widely distributed fields in the upper drainage basin. Development has been accelerated in recent years. Extensive oil shale deposits are estimated to contain 80 percent of the recoverable oil in shale in the United States. Important deposits of bituminous sandstone and rare hydrocarbons are also found.

The upper drainage basin is the leading domestic source of vanadium, uranium, molybdenum, and radium ore. Zinc, lead, silver, and gold are commercially important. Estimated reserves of phosphate rock amount to a total of 1.6 billion tons, part of which could be mined by open-pit methods.

Timber stands are widely distributed over the upper drainage basin but are most heavily concentrated in western Colorado. Present development is largely for local uses. A large pulping plant is planned.

The upper drainage basin contains more than a million and a half acres of arable dry land. Only about 272,000 acres, however, are capable of producing crops without irrigation. Extensive good land in adjoining areas now receives some water from the Colorado River system. Additional diversions are desired for this land.

The extent of the upper drainage basin's water resources is indicated by an estimated 32-year average virgin or undepleted flow at Lee Ferry of 15,638,000 acre-feet annually. Average depletions from present and authorized water uses, including exportations from the drainage basin, are estimated at a total of 2,548,000 acre-feet annually. These depletions will leave an actual average yearly flow at Lee Ferry of 13,090,000 acre-feet. Under the terms of the Colorado River Compact and the Mexican Water Treaty nearly 5 million acre-feet of this amount will be available for further development in the upper basin.

Tributary streams as they descend from their mountain sources offer numerous opportunities for the development of hydroelectric power. By far the greatest opportunities for power development are on the main river and its major tributaries which flow for many hundreds of miles deeply entrenched in narrow canyons.

Economic Conditions

General Conditions

The prosperity of agriculture in the Upper Colorado River Drainage Basin generally reflects the prosperity of the livestock industry, the dominant agricultural pursuit. With vast areas of fine range land available for summer grazing, livestock production is limited by the production of hay for winter feed. Hay production, in turn, is determined largely by the irrigation supply, and in many instances the supply is undependable because of lack of reservoirs for stream regulation. Drouth periods of the past have brought hardship to the livestock industry and to agriculture generally. In these periods relief loads have been unusually high. For the past decade high agricultural prices and favorable water supplies have been responsible for general prosperity on farms and ranches. A

notable exception is the case of the Navajo Indians in the San Juan River Basin where extensive outside help has been necessary to allay conditions of abject poverty.

Intensified development of mineral resources in recent years has created new employment opportunities, including off-the-farm work for many farmers. The increase in population resulting from new job opportunities has created new markets for locally produced and imported products, has taxed municipal facilities and water supplies in several areas, and has increased demands for electric energy. Raw materials are stimulating industrial activities in areas adjoining the upper drainage basin, particularly areas near Denver, Pueblo, Provo, and Salt Lake City.

Community Needs

The development of water resources is a critical need of the upper drainage basin. Dependable irrigation supplies are needed to stabilize existing agriculture and to make productive tracts of arable dry land that now yield only scanty range forage. Water, and the power that can be generated by water, are required to serve the growing population and to aid in the processing of the upper basin's vast mineral resources. Farm lands, industries, and municipalities in adjoining areas that by definition are potentially parts of the upper basin are in need of water from the Colorado River. These adjoining areas also urgently need electric energy that could be generated in the canyons of the Colorado River and its tributaries.

Water Compacts and Treaty

Two compacts between interested States and a treaty between the United States and Mexico govern the division of Colorado River waters. The Colorado River Compact of 1922 allocates waters to the upper and lower basins. Waters allocated the upper basin are divided among the States in the upper basin by the Upper Colorado River Basin Compact of 1949. The Mexican Water Treaty of 1945 defines Mexico's rights to the use of water from the Colorado River system.

Colorado River Compact

The Colorado River Compact, signed November 24, 1922, and subsequently ratified by all signatory States and approved by Congress, has often been referred to as the "law of the river."

Articles II and III of the Colorado River Compact are of particular significance and are quoted in full as follows:

ARTICLE II

"As used in this compact:

"(a) The term 'Colorado River system' means that portion of the Colorado River and its tributaries within the United States of America.

"(b) The term 'Colorado River Basin' means all of the drainage area of the Colorado River system and all other territory within the United States of America to which the waters of the Colorado River system shall be beneficially applied.

"(c) The term 'States of the upper division' means the States of Colorado, New Mexico, Utah, and Wyoming.

"(d) The term 'States of the lower division' means the States of Arizona, California, and Nevada.

"(e) The term 'Lee Ferry' means a point in the main stream of the Colorado River 1 mile below the mouth of the Paria River.

"(f) The term 'Upper Basin' means those parts of the States of Arizona, Colorado, New Mexico, Utah, and Wyoming within and from which waters naturally drain into the Colorado River system above Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system above Lee Ferry.

"(g) The term 'Lower Basin' means those parts of the States of Arizona, California, Nevada, New Mexico, and Utah within and from which waters naturally drain into the Colorado River system below Lee Ferry, and also all parts of said States located without the drainage area of the Colorado River system which are now or shall hereafter be beneficially served by waters diverted from the system below Lee Ferry.

"(h) The term 'domestic use' shall include the use of water for household, stock, municipal, mining, milling, industrial, and other like purposes, but shall exclude the generation of electrical power.

ARTICLE III

"(a) There is hereby apportioned from the Colorado River system in perpetuity to the upper basin and to the lower basin, respectively, the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum, which shall include all water necessary for the supply of any rights which may now exist.

"(b) In addition to the apportionment in paragraph (a), the lower basin is hereby given the right to increase its beneficial consumptive use of such waters by 1,000,000 acre-feet per annum.

"(c) If, as a matter of international comity, the United States of America shall hereafter recognize in the United States of Mexico any right to the use of any waters of the Colorado River system, such waters shall be supplied first from the waters which are

> surplus over and above the aggregate of the quantities specified in paragraphs (a) and (b); and if such surplus should prove insufficient for this purpose, then, the burden of such deficiency shall be equally borne by the Upper Basin and the Lower Basin, and whenever necessary the States of the Upper Division shall deliver at Lee Ferry water to supply one-half of the deficiency so recognized in addition to that provided in paragraph (d).
>
> "(d) The States of the upper division will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of 10 consecutive years reckoned in continuing progressive series beginning with the first day of October next succeeding the ratification of this compact.
>
> "(e) The States of the upper division shall not withhold water, and the States of the lower division shall not require the delivery of water, which can not reasonably be applied to domestic and agricultural uses.
>
> "(f) Further equitable apportionment of the beneficial uses of the waters of the Colorado River system unapportioned by paragraphs (a), (b), and (c) may be made in the manner provided in paragraph (g) at any time after October 1, 1963, if and when either basin shall have reached its total beneficial consumptive use as set out in paragraphs (a) and (b).
>
> "(g) In the event of a desire for further apportionment as provided in paragraph (f) any two signatory States, acting through their governors, may give joint notice of such desire to the governors of the other signatory States and to the President of the United States of America, and it shall be the duty of the governors of the signatory States and of the President of the United States of America forthwith to appoint representatives, whose duty it shall be to divide and apportion equitably between the upper basin and lower basin the beneficial use of the unapportioned water of the Colorado River system as mentioned in paragraph (f), subject to the legislative ratification of the signatory States and the Congress of the United States of America."

Mexican Water Treaty

The treaty between the United States of America and the United States of Mexico, effective November 8, 1945, allots to Mexico a guaranteed annual quantity of 1,500,000 acre-feet to be delivered in accordance with a schedule specifically set out in the treaty. When the United States Section of the International Boundary Commission decides that there is a surplus of water in the Colorado River in excess of the amount necessary to supply uses in the United States and the guaranteed quantity of 1,500,000 acre-feet allotted to Mexico, the United States, by the express terms of the treaty, would undertake to provide a total quantity of 1,700,000 acre-feet to Mexico. Provision is made in the treaty for reduction of the guaranteed quantity to be delivered to Mexico in the

event of extraordinary drought or serious accident to the irrigation system in the United States.

Upper Colorado River Basin Compact

By the Upper Colorado River Basin Compact, approved by Congress April 6, 1949, the use of water apportioned the upper basin under the Colorado River Compact is divided among the upper basin States. The upper basin compact also establishes the obligations of each State of the upper division with respect to the deliveries of water required to be made at Lee Ferry by the Colorado River Compact.

Article III of the compact, part of which is quoted below, provides for the apportionment of the consumptive use of water.

> "(a) Subject to the provisions and limitations contained in the Colorado River Compact and in this compact, there is hereby apportioned from the Upper Colorado River system in perpetuity to the States of Arizona, Colorado, New Mexico, Utah, and Wyoming, respectively, the consumptive use of water as follows:
>
> (1) To the State of Arizona the consumptive use of 50,000 acre-feet of water per annum.
>
> (2) To the States of Colorado, New Mexico, Utah, and Wyoming, respectively, the consumptive use per annum of the quantities resulting from the application of the following percentages to the total quantity of consumptive use per annum apportioned in perpetuity to and available for use each year by the upper basin under the Colorado River Compact and remaining after the deduction of the use, not to exceed 50,000 acre-feet per annum, made in the State of Arizona.

State of Colorado	51.75 per cent,
State of New Mexico	11.25 per cent,
State of Utah	23.00 per cent,
State of Wyoming	14.00 per cent."

Article IV outlines certain principles to be applied in determining the extent to which each State of the upper division will be required to curtail its apportioned consumptive use if a curtailment is necessary to permit the States to meet the Lee Ferry flow obligations provided in Article III of the Colorado River Compact.

Article V pertains largely to the charging of storage losses. Paragraph (c) of this article, quoted below, is concerned with the use of reservoir sites and is of importance in the development of the water resources of the States of the upper division.

> "(c) In the event the Commission finds that a reservoir site is available both to assure deliveries at Lee Ferry and to store

> water for consumptive use in a State of the Upper Division, the storage of water for consumptive use shall be given preference. Any reservoir or reservoir capacity hereafter used to assure deliveries at Lee Ferry shall by order of the Commission be used to store water for consumptive use in a State, provided the Commission finds that such storage is reasonably necessary to permit such State to make the use of the water apportioned to it by this Compact."

Article VI, quoted below, provides for a determination of the quantity of the consumptive use of water for the upper basin and for each State of the upper basin.

> "The Commission shall determine the quantity of the consumptive use of water, which use is apportioned by Article III hereof, for the upper basin and for each State of the upper basin by the inflow-outflow method in terms of man-made depletions of the virgin flow at Lee Ferry, unless the Commission, by unanimous action, shall adopt a different method of determination."

Article VIII creates an interstate administrative agency to be known as the Upper Colorado River Commission. This article provides that the commission be composed of one commissioner representing each of the States of the upper division, designated or appointed in accordance with the laws of each such State and, if designated by the President, one Commissioner representing the United States of America.

In anticipation of projects which require diversion and storage of water in one State for use in another State, Article IX is included in the compact. This article, part of which is quoted in the following paragraphs, is of significance to the Colorado River Storage project because, as to the appropriations of Colorado River water, it supersedes existing statutory law in some of the upper basin States which deny the right to divert water in one State for use in another State.

> "(a) No State shall deny the right of the United States of America and, subject to the conditions hereinafter contained, no State shall deny the right of another signatory State, any person, or entity of any signatory State to acquire rights to the use of water, or to construct or participate in the construction and use of diversion works and storage reservoirs with appurtenant works, canals and conduits in one State for the purpose of diverting, conveying, storing, regulating, and releasing water to satisfy the provisions of the Colorado River Compact relating to the obligation of the States of the upper division to make deliveries of water at Lee Ferry, or for the purpose of diverting, conveying, storing, or regulating water in an upper signatory State for consumptive use in a lower signatory State, when such use is within the

> apportionment to such lower State made by this Compact. Such rights shall be subject to the rights of water users, in a State in which such reservoir or works are located, to receive and use water, the use of which is within the apportionment to such State by this Compact."

Article IX also provides for acquisition of out-of-State property by donation, purchase, or through the exercise of the power of eminent domain. In addition it provides for administration of water control facilities in one State for use of water in another State.

Investigations and Reports

Previous Investigations

Investigations of means to develop the waters of the Upper Colorado River system were started by the Bureau of Reclamation in 1902, the year of the Bureau's organization. Within 3 years two major projects in the upper basin, the Uncompahgre in Colorado and the Strawberry Valley in Utah, were authorized for construction. A few years later the Grand Valley project in Colorado also was authorized. No significant action was then taken until 1928 when Congress, recognizing the need for further development, wrote into the Boulder Canyon Project Act a directive to the Secretary of the Interior to make investigations and publish reports on the feasibility of projects for irrigation, power, and other multiple uses for the purpose of formulating a comprehensive scheme of control and the improvement and utilization of the water of the Colorado River and its tributaries. In accordance with the Congressional mandate, work was undertaken after 1928 on the tremendous task of classifying lands in the upper drainage basin, making water supply studies on the numerous tributary streams, and locating and investigating reservoir and canal sites. Prior to completion of these studies the Colorado-Big Thompson project and a few smaller projects were selected for construction. The basin-wide studies, retarded by the war, were reported in a publication of March 1946, entitled The Colorado River, a comprehensive report on the development of the water resources of the Colorado River Basin. The report was later printed as House Document 419, Eightieth Congress, First Session. The report includes a description of the basin, its natural resources, needs, and problems. It describes present developments in the basin and presents a descriptive inventory of potential developments.

The Colorado River report lists 134 projects as possibilities for future development of water resources within the natural drainage basin of the Colorado River. One hundred of these projects are located in the upper drainage basin. The report also lists potential projects for the export of water from the Colorado River system to adjoining basins. It points out that a comprehensive plan of water resources development could

not be formulated until further detailed investigations were made and allotments of Colorado River water made to each of the States of the upper and lower basins. The report provided a basis for compact negotiations among the upper basin States which resulted in their compact of 1949.

Cooperating with the Bureau of Reclamation in the basin-wide investigations and contributing to the 1946 report were other agencies of the Department of the Interior including the Geological Survey, National Park Service, Fish and Wildlife Service, Grazing Service, Bureau of Mines, Office of Indian Affairs, and General Land Office. The Forest Service of the Department of Agriculture and the Federal Power Commission also contributed to the report.

Scope of Present Investigations

Investigations leading to the present report have been conducted since 1946 to determine in greater detail than was done in the basin investigation the most attractive plan for providing river regulation, sediment retention, power production, and other benefits on the Colorado River and its major tributaries above Lee Ferry. The investigations have been carried out in sufficient detail to establish an over-all plan and to determine its engineering and economic feasibility. The various dams and other related works required by the plan are collectively designated the Colorado River Storage project.

The main stream investigations have been closely correlated with concurrent studies made of various projects to utilize the waters of the Upper Colorado River system for irrigation and other purposes. Correlations have been made from the standpoints of water supply and storage requirements, and suggested financial relationships have been developed through which surplus power revenues of the Colorado River Storage project would be used to assist irrigators in payment of costs of other projects that would utilize water of the Upper Colorado River system. Projects that would be so assisted are referred to as "participating projects." Detailed reports have been completed on some participating projects and others are being prepared. All projects authorized subsequent to approval of the Upper Colorado River Basin Compact that would consume water of the Upper Colorado River system are considered to be dependent on the storage project for an assured water supply. Such projects therefore are designated "dependent projects."

Acknowledgments

This report has been prepared by the Department of the Interior and assembled under sponsorship of the Bureau of Reclamation. Important contributions to the report were made by the Upper Colorado River Compact Commission and States of the Upper Colorado River Basin. Information also was obtained from the Federal Power Commission and other Federal agencies.

CHAPTER II

PLAN OF DEVELOPMENT

The Colorado River Storage project would provide the long-time regulatory storage needed to permit States of the upper division to meet their flow obligation at Lee Ferry, as defined in Article III (d) of the Colorado River Compact, and still utilize their apportioned water. During periods of low stream flow, the States would release storage water to meet the Lee Ferry flow obligation and in exchange they would divert upstream flow for use in the upper basin. The project would provide some storage water for direct use in the upper basin. In addition, the project would control sediment, abate floods, facilitate recreational development, and aid in fish and wildlife conservation. It also would permit production of a substantial amount of the electric energy needed in the upper basin and adjacent areas. Revenues from the sale of project-generated power would be sufficient to pay all reimbursabl Colorado River Storage project costs and to assist irrigators in payment of costs of other projects that would utilize waters of the Upper Colorado River system.

Colorado River Storage Project

Project Works

Eight major storage dams and two high dams providing only minor storage would be constructed on the Colorado River and its principal tributaries above Lee Ferry. The reservoirs formed by the dams would have a total capacity of 48,555,000 acre-feet. Power plants and other appurtenant facilities would be provided at each dam and necessary transmission lines would be built.

The highest dam and the one creating more initial storage capacity than all others combined would be the Glen Canyon Dam of the Glen Canyon unit. This dam, only 17 miles upstream from Lee Ferry, would be a key structure in controlling water releases to the lower basin and in impounding the heavy silt accumulations which enter the river in the southern part of the upper basin. It is the only dam planned on the Upper Colorado River proper.

Four of the dams would be on the Green River. In order, moving upstream, these would be the Gray Canyon Dam of the Gray Canyon unit, Split Mountain Dam of the Split Mountain unit, Echo Park Dam of the Echo Park unit, and the Ashley Dam of the Flaming Gorge unit. The Split Mountain Dam would provide no active storage capacity and would be useful primarily for power generation, with stream regulation provided by the

Echo Park Dam only 21 river miles upstream. The Echo Park Dam, located 3 river miles below the junction of the Green and Yampa Rivers, would back water up both streams, creating the system's second largest reservoir. Above Echo Park on the Yampa River would be the Cross Mountain Dam.

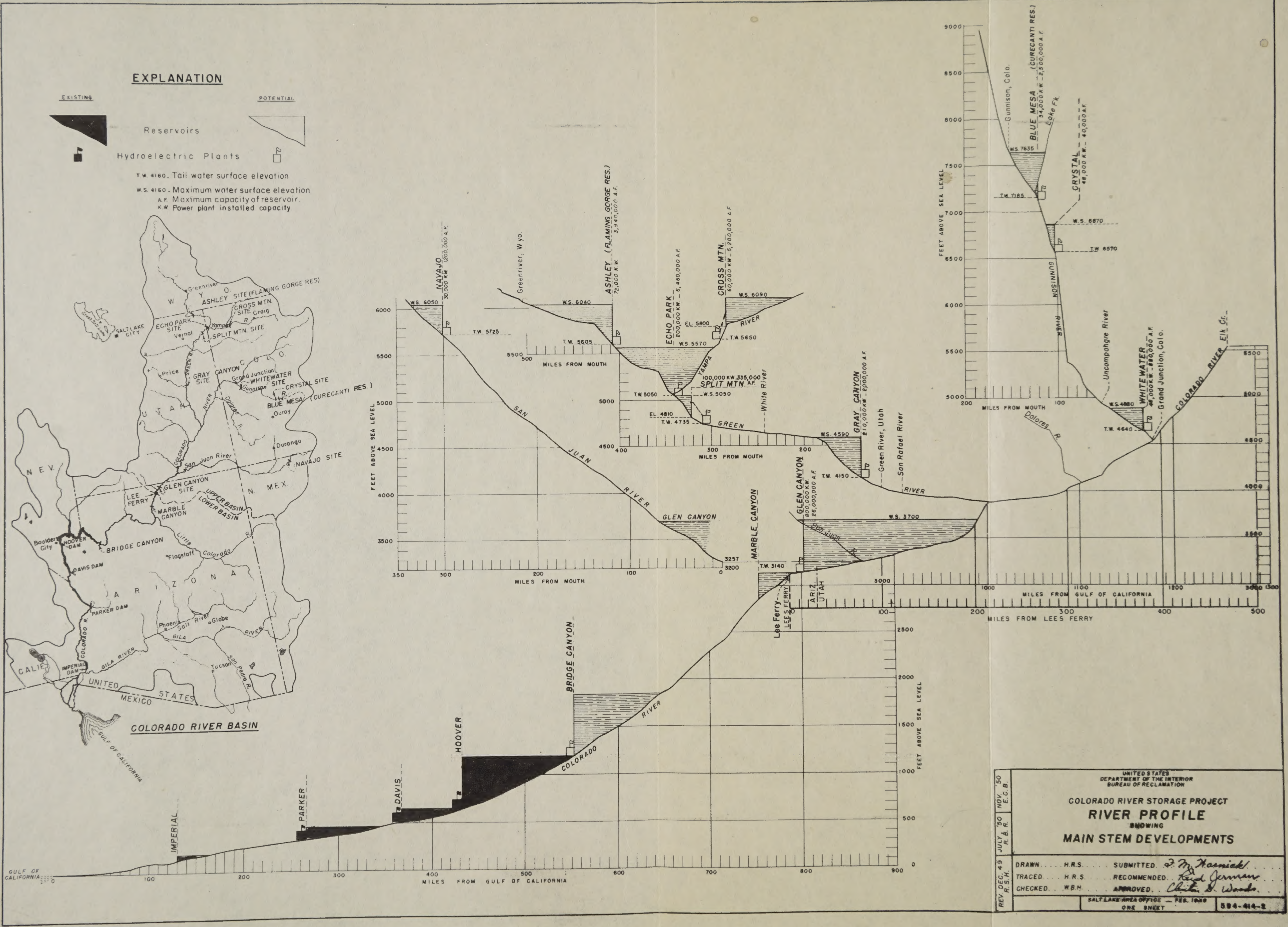
The Whitewater Dam of the Whitewater unit would be located on the Gunnison River 15 river miles above Grand Junction, Colo. Above the Whitewater Dam would be Crystal Dam of the Crystal unit which would have limited storage and the Blue Mesa Dam of the Curecanti unit which would provide storage regulation for its own and the Crystal power plants. The Navajo Dam of the Navajo unit would be located on the San Juan River about 19.5 river miles upstream from Blanco, N. Mex.

Locations of the potential project units are shown on the profile on the following page. The profile also shows the locations of existing and potential developments in the lower basin. Detailed data on the structures included in the various project units are given in Chapter III, Designs and Estimates.

Regulatory Storage

A capacity of 23,000,000 acre-feet would be reserved in project reservoirs for long-time regulatory storage. The water stored would be released as needed in drouth periods to meet the compact obligation at Lee Ferry. The reservoirs would be refilled during years of favorable water supply. In a dry decade such as that of 1931-1940, release of the entire 23,000,000 acre-feet would be necessary to meet the Lee Ferry obligation. A storage release in that amount would be necessary even if water uses in the upper basin were naturally curtailed by the drough, resulting in a depletion at Lee Ferry somewhat less than the compact-permitted 7,500,000 acre-feet annually.

Present flows in the upper basin are adequate to meet the 10-year Lee Ferry obligation. Within 20 or 25 years, however, the depletions are expected to increase to the extent that curtailment of consumptive uses will be necessary in protracted dry periods unless some storage water is available for delivery to the lower basin. If the required storage works are to be available when needed, steps toward construction should be taken immediately. An extended construction period will be required and the reservoirs should be filled initially while unused apportioned water is available. The amount of storage capacity, if any, required for assistance in the administration of the Mexican Water Treaty cannot be determined at this time. The plan outlined herein does not provide for, nor preclude, storage for this purpose. It is assumed, however, that any additional water required at Lee Ferry for Mexican use will be made available by applying the principles of curtailment outlined in Article IV of the Upper Colorado River Basin Compact.


EXPLANATION
EXISTING
POTENTIAL
Reservoirs
Hydroelectric Plants
T.W. 4160 _ Tail water surface elevation
W.S. 4160 _ Maximum water surface elevation
A.F. Maximum capacity of reservoir.
K.W. Power plant installed capacity
COLORADO RIVER BASIN
W Y O.
Greenriver
ASHLEY SITE (FLAMING GORGE RES)
CROSS MTN. SITE
Craig
ECHO PARK SITE
Yampa R.
SALT LAKE CITY
Vernal
SPLIT MTN. SITE
Price
GRAY CANYON SITE
COLO.
Grand Junction
WHITEWATER SITE
Gunnison
CRYSTAL SITE
BLUE MESA (CURECANTI RES.)
Ouray
Dolores R.
UTAH
Durango
San Juan River
NAVAJO SITE
NEV.
GLEN CANYON SITE
LEE FERRY
UPPER BASIN
LOWER BASIN
MARBLE CANYON
N. MEX.
Boulder City
HOOVER DAM
BRIDGE CANYON
Little Colorado R.
Flagstaff
DAVIS DAM
ARIZONA
PARKER DAM
Phoenix
Salt River
Globe
GILA RIVER
CALIF.
IMPERIAL DAM
Tucson
San Pedro R.
UNITED STATES
MEXICO
GULF OF CALIFORNIA
NAVAJO 30,000 KW (200,000 A.F.)
W.S. 6050
T.W. 5725
SAN JUAN RIVER
GLEN CANYON
3257
FEET ABOVE SEA LEVEL
6000
5500
5000
4500
4000
3500
3200
350
300
200
100
0
MILES FROM MOUTH
Greenriver, Wyo.
ASHLEY (FLAMING GORGE RES.) 72,000 KW 3,940,000 A.F.
W.S. 6040
T.W. 5605
ECHO PARK 200,000 KW _ 6,460,000 A.F.
CROSS MTN. 60,000 KW _ 5,200,000 A.F.
W.S. 6090
EL. 5800
T.W. 5650
W.S. 5570
YAMPA RIVER
100,000 KW 335,000 A.F.
SPLIT MTN.
W.S. 5050
T.W. 5050
EL. 4810
T.W. 4735
White River
GREEN RIVER
GRAY CANYON 210,000 KW _ 2,000,000 A.F.
W.S. 4590
T.W. 4150
Green River, Utah
San Rafael River
500
400
MARBLE CANYON
GLEN CANYON 800,000 KW 26,000,000 A.F.
W.S. 3700
San Juan
T.W. 3140
Lee Ferry
LEES FERRY
ARIZ. UTAH
3000
1000
1100
1200
1300
MILES FROM GULF OF CALIFORNIA
MILES FROM LEES FERRY
9000
8500
8000
7500
7000
6500
Gunnison, Colo.
BLUE MESA (CURECANTI RES.) 54,000 KW _ 2,500,000 A.F.
Lake Fk.
W.S. 7635
T.W. 7185
CRYSTAL 48,000 KW _ 40,000 A.F.
W.S. 6870
T.W. 6570
GUNNISON RIVER
Uncompahgre River
WHITEWATER 48,000 KW _ 880,000 A.F.
W.S. 4880
T.W. 4640
Grand Junction, Colo.
Dolores R.
COLORADO RIVER
Elk Cr.
BRIDGE CANYON
COLORADO RIVER
HOOVER
DAVIS
PARKER
IMPERIAL
GULF OF CALIFORNIA
2500
2000
1500
500
0
100
600
700
800
900
MILES FROM GULF OF CALIFORNIA

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER STORAGE PROJECT

RIVER PROFILE
SHOWING
MAIN STEM DEVELOPMENTS

NOV. '50 E.C.B.

JULY '50 R.B.R.

REV. DEC. 49 R.S.H.

DRAWN . . . . H.R.S.	SUBMITTED . F. M. Warnick
TRACED . . . H.R.S.	RECOMMENDED . . Reid Jerman
CHECKED . . W.B.H.	APPROVED . . Clinton D. Woods

SALT LAKE AREA OFFICE — FEB. 1949
ONE SHEET

584-414-2

Irrigation and Other Water-Consuming Uses

Reservoirs planned for the Colorado River Storage project would be located too low on the streams to provide water directly to major segments of lands and to industrial centers in the upper basin. In some instances, however, direct uses would be possible. At the Flaming Gorge Reservoir, for instance, an inactive storage pool of almost a million acre-feet would be maintained to permit a gravity diversion to the Uinta Basin as contemplated under the Central Utah project. Also, a considerable amount of active capacity in the reservoir would be provided for regulation of the water reserved for direct diversion. As an alternative, water for the Uinta Basin could be provided by pumping from Echo Park Reservoir. Gunnison River water could be diverted from Whitewater Reservoir above an inactive storage pool of 410,000 acre-feet and conveyed to Grand Valley to replace water now provided from the Colorado River. In exchange, the Colorado River water would become available to potential upstream developments including export diversions. Active capacity in the Whitewater Reservoir would be required to provide regulation for the replacement diversion. The entire active capacity of the Navajo Reservoir would eventually be required to regulate San Juan River water for potential developments both upstream and downstream on the San Juan River. Water from the Navajo Reservoir could directly supply the Shiprock project (Indian), the South San Juan project, or by exchange it could benefit possible projects for the exportation of water to the Rio Grande River Basin in Colorado and New Mexico.

Capacities in the Flaming Gorge, Whitewater, and Navajo Reservoirs reserved to regulate water for use in the upper basin, if not required immediately for that purpose, could serve in the interim to facilitate the generation of electric energy.

As additional investigations are made, it may be found desirable to use other Colorado River Storage project reservoirs to store water for irrigation and other consumptive uses in the States of the upper division. Preference to the use of reservoirs for such storage is given in Article V (b) of the Upper Colorado River Basin Compact over the use of reservoirs for assurance of deliveries at Lee Ferry.

Sediment Control

A total capacity of about 20,000,000 acre-feet would be provided in project reservoirs to accommodate the sediment that would be deposited in a period of 200 years. With reduced erosion of the watersheds by improved practices of land management agencies, the period of protection against sediment encroachment would be extended. In the future it may also be desirable to develop other sediment storage sites in the upper basin.

More than three-fourths of the sediment in the river will enter the river below all potential reservoirs except Glen Canyon. Fortunately, ample sediment storage capacity can be economically developed in the Glen Canyon Reservoir to protect present and future reservoirs in the lower basin from sediment encroachment. Next largest capacities for sediment retention would be provided at the Flaming Gorge and Gray Canyon Reservoirs on the Green River.

A part of the sediment would be carried into the lower levels of the reservoirs where it would occupy inactive reservoir capacity. The major part, however, would settle in shallower reservoir areas and reduce the active capacity useful for other purposes.

Power Production

Power plants would be installed as project features to utilize the regulated river flows and the hydrostatic heads at project dams for the generation of electric energy. The plants would have a total generating capacity of 1,622,000 kilowatts. Initially, with all the units in coordinated operation, they would have a firm annual output of about 9,000,000,000 kilowatt-hours and with ultimate development in the upper basin they would have a firm annual output of about 6,000,000,000 kilowatt-hours.

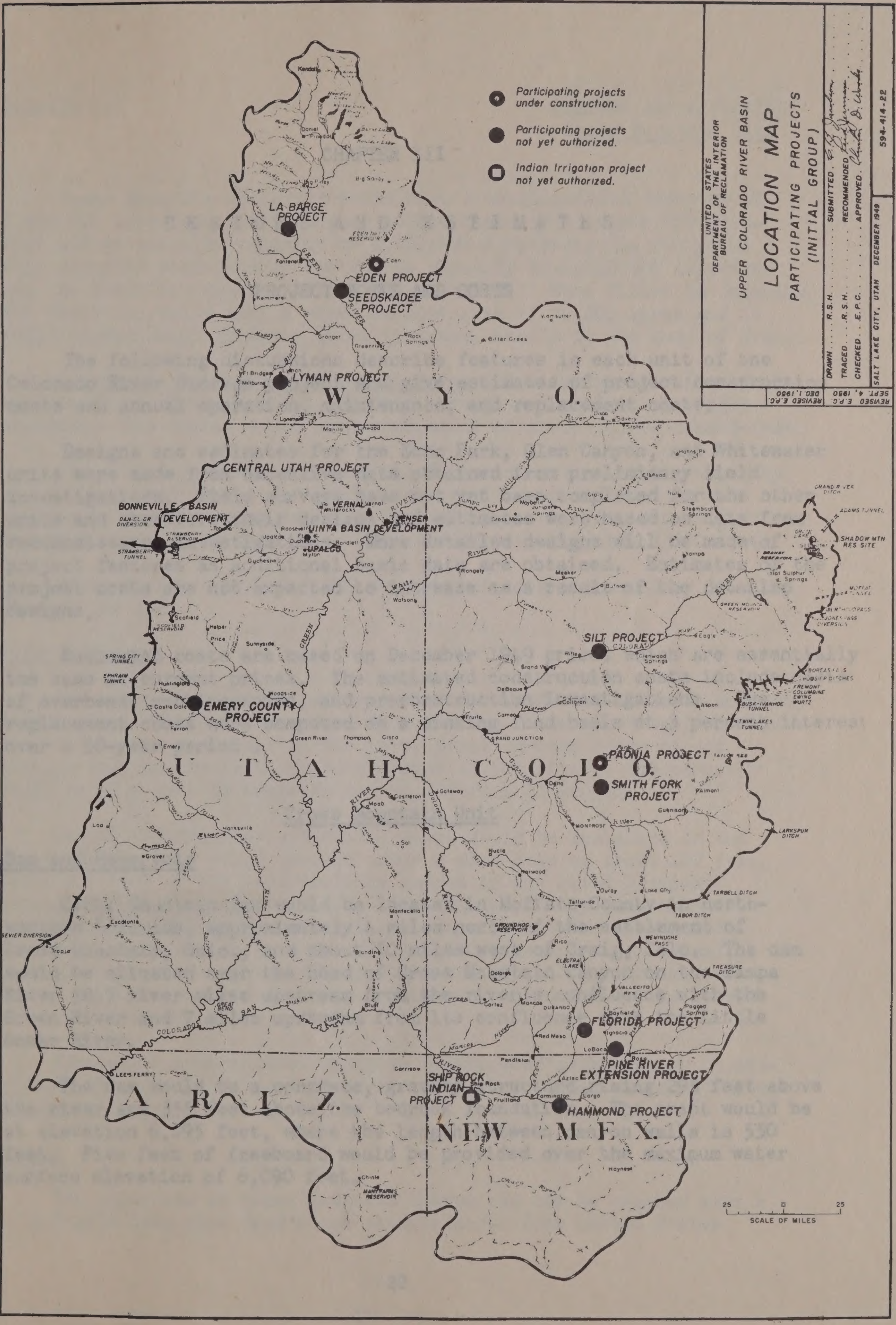
Hydrostatic heads at the dams would vary with changes in reservoir content. Minimum power pool elevations, however, would be maintained at project reservoirs. To aid in creating power heads a minimum inactive capacity of about 11,000,000 acre-feet would initially be provided. Although more than 8,000,000 acre-feet of this capacity would eventually be occupied by sediment, it would still be useful in maintaining the power heads. Until needed for river regulation, the active capacity would also be used to assist in power production.

Participating Projects

In general, future projects for irrigation and other water-consuming uses in the upper basin will be complex and expensive to construct since the most dependable water supplies and the most favorable construction sites are already developed. New projects, as a rule, will require individual storage reservoirs in addition to the large regulatory reservoirs of the Colorado River Storage project. In many instances, the new projects will require the construction of long tunnels and siphons or canals over difficult terrain.

Because of their relatively high cost, the irrigation features of most of the projects could not be paid for by those who would benefit directly. The far-reaching indirect benefits, however, would justify

the giving of financial assistance from other sources. Such assistance could be provided from power revenues of the Colorado River Storage project. A suggested financial arrangement requiring the establishment of the Upper Colorado River Account and qualifying criteria for participating projects are discussed in the chapter, Financial Analysis. Projects suggested by the States of the Upper Colorado River Basin for early assistance from the account include the Eden and Paonia, now under construction, and the Central Utah (initial phase), Emery County, Florida, Hammond, LaBarge, Lyman, Pine River extension, Seedskadee, Silt, and Smith Fork.


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
UPPER COLORADO RIVER BASIN
LOCATION MAP
PARTICIPATING PROJECTS
(INITIAL GROUP)
DRAWN R.S.H.
TRACED R.S.H.
CHECKED E.P.C.
SUBMITTED
RECOMMENDED
APPROVED
SALT LAKE CITY, UTAH DECEMBER 1949
594-414-22
REVISED E.P.C. SEPT. 4, 1950
REVISED E.P.C. DEC 1, 1950
Participating projects under construction.
Participating projects not yet authorized.
Indian Irrigation project not yet authorized.
LA BARGE PROJECT
EDEN PROJECT
SEEDSKADEE PROJECT
LYMAN PROJECT
CENTRAL UTAH PROJECT
BONNEVILLE BASIN DEVELOPMENT
VERNAL
JENSEN
UINTA BASIN DEVELOPMENT
UPALCO
EMERY COUNTY PROJECT
SILT PROJECT
PAONIA PROJECT
SMITH FORK PROJECT
FLORIDA PROJECT
PINE RIVER EXTENSION PROJECT
SHIP ROCK INDIAN PROJECT
HAMMOND PROJECT
W Y O.
U T A H
C O L O.
A R I Z.
NEW MEX.
GREEN RIVER
COLORADO
SAN JUAN
25 0 25
SCALE OF MILES

CHAPTER III

DESIGNS AND ESTIMATES

PROJECT WORKS AND COSTS

The following discussions describe features in each unit of the Colorado River Storage project and give estimates of project construction costs and annual operation, maintenance, and replacement costs.

Designs and estimates for the Echo Park, Glen Canyon, and Whitewater units were made from extensive data obtained from preliminary field investigations. Field surveys have not yet been completed for the other units and therefore their designs and estimates were based on data from reconnaissance investigations. More detailed designs will be made of project features as additional basic data are obtained. Estimates of the project costs are not expected to increase as a result of the detailed designs.

Estimated costs are based on December 1949 prices which are essentially the same as current prices. The estimated construction costs include costs of overhead, contingencies, and preconstruction investigations. The replacement costs were computed on a sinking fund basis at 3 percent interest over a 50-year period.

Cross Mountain Unit

Dam and Reservoir

Cross Mountain Dam would be located in Moffatt County in northwestern Colorado, approximately 4 miles north of the settlement of Cross Mountain, Colo., and about 50 miles west of Craig, Colo. The dam would be situated near the head of Cross Mountain Canyon on the Yampa River 58.5 river miles upstream from the river's confluence with the Green River and 7 miles upstream from its confluence with the Little Snake River.

The dam would be a concrete, gravity structure, rising 295 feet above the river and 355 feet above the bedrock foundation. The crest would be at elevation 6,095 feet, where the length between canyon walls is 550 feet. Five feet of freeboard would be provided over the maximum water surface elevation of 6,090 feet.

Cross Mountain Reservoir would have a total initial capacity of 5,200,000 acre-feet, including an active capacity of 4,200,000 acre-feet and an inactive capacity of 1,000,000 acre-feet. In 200 years silt deposits would reduce the active capacity to 4,030,000 acre-feet and the inactive capacity to 887,000 acre-feet. When filled to capacity, the reservoir would have a water surface area of 52,200 acres and it would extend about 76 river miles upstream, nearly to the town of Craig.

Diversion, spillway, and outlet works. During construction of the dam the Yampa River would be diverted through a tunnel in the right abutment. The tunnel would have a capacity of about 10,000 second-feet.

The spillway would be a controlled-type structure with a capacity of 45,000 second-feet. It would discharge into an inclined tunnel leading to the diversion tunnel. Control of the spill would be provided by two 20-foot by 70-foot gates over a crest at elevation 6,070 feet.

River outlet works of 5,000 second-foot capacity would be provided through the dam.

Power Features

The power plant would be located at the lower end of Cross Mountain Canyon, about 3 miles downstream from the dam. The water would be conducted from the reservoir to the power plant through a tunnel cut through rock on the left, or south, side of the river. The tunnel would be 17.5 feet in diameter and 11,700 feet in length.

Two 30,000-kilowatt generating units would be installed in the power plant. They would operate under a mean head of about 400 feet. About 150 feet of the head would be gained in the river gradient through the canyon below the dam. The initial energy generation of the Cross Mountain plant with all the project units in coordinated operation would amount to about 330,000,000 kilowatt-hours annually. With ultimate upstream depletions approximately 310,000,000 kilowatt-hours could be produced annually. Tailwater elevation at the power plant would be about 5,650 feet.

Transmission facilities would be constructed as necessary to distribute the electric energy produced to various load centers and interconnection points.

Access

The upper end of Cross Mountain Canyon can now be reached over a 4- or 5-mile long dirt road which extends north from United States

Highway No. 40 at the settlement of Cross Mountain. The distance from the upper end of the canyon to the dam site, about 3,000 feet, must be traveled by foot. An access road for construction purposes would follow the general route of the existing dirt road over gently rolling terrain. After entering the canyon, the road would follow the river to the dam site.

Rights-of Way and Relocation

The reservoir area contains 3,150 acres of farm land and three small centers of population, Sunbeam, Maybell, and Juniper Springs, with a combined population of about 100. United States Highway No. 40 and an oil pipe line cross the reservoir area and would require relocation. The length of each of these facilities within the reservoir area is approximately 20 miles. In connection with the relocation of the pipe line, a pumping station at Sunbeam, consisting of six diesel units, would also have to be moved.

Geology

Geological conditions at the Cross Mountain Dam site are favorable for construction of the type of dam contemplated. The foundation bedrock is quartzite and quartzose sandstone of the highest quality. The bedrock, however, contains some open fractures which would require grouting. Foundation drilling showed the maximum depth of river fill to be 45 feet. The drilling disclosed no unfavorable geologic conditions except the rock fractures. The general quality of the rock is excellent. After grouting of the fractures the bearing capacity of the foundation would be high and entirely competent to support either a gravity- or arch-type concrete dam.

Suitable construction materials can be found along the banks of the Yampa River near Sunbeam, about 11 miles upstream from the dam site. Riprap is available in unlimited quantities immediately downstream from the dam site.

Cost Estimates

Estimated costs of the Cross Mountain unit, based on December 1949 prices, are summarized in the table on the following page.

ESTIMATED COSTS OF CROSS MOUNTAIN UNIT

Feature	Construction costs	Annual costs: Operation and maintenance costs	Annual costs: Replacement costs	Annual costs: Total
Dam and reservoir	$22,700,000	$ 27,000	$ 4,700	$ 31,700
Access road	300,000			
Rights-of-way and relocation	7,900,000			
Construction camp	500,000			
Power plant	6,300,000	122,300	56,200	178,500
Power tunnel	5,200,000			
Transmission system	8,100,000	113,000	91,500	204,500
Total	$51,000,000	$262,300	$152,400	$414,700

Crystal Unit

Dam and Reservoir

Crystal Dam would be located on the Gunnison River about 14 miles east of Montrose, Colo.

Crystal Dam would be a concrete, gravity-type structure. It would rise 305 feet above the river and 355 feet above the assumed bedrock foundation. The crest would be at elevation 6,875 feet, 5 feet above the maximum water surface elevation. The distance between the canyon walls at the crest elevation is about 620 feet.

Crystal Reservoir would have a capacity of 40,000 acre-feet. The entire capacity is considered inactive since it would serve only to maintain a power head and to regulate the hourly and daily releases from the Curecanti Reservoir. Because of its location below Curecanti Reservoir, the Crystal Reservoir would not receive significant quantities of sediment. When full, Crystal Reservoir would cover about 560 acres and would extend about 10 river miles up the Gunnison River.

Diversion, spillway, and outlet works. A tunnel with a capacity of 22,500 second-feet would be constructed through the left abutment to divert the river flow during construction of the dam.

The spillway, with a capacity of 48,000 second-feet, would discharge through an inclined tunnel leading to the diversion tunnel. Control of the spill would be provided by two 26-foot by 50-foot gates over a crest at elevation 6,844 feet.

The river outlet works would have a capacity of 2,000 second-feet.

Power Features

The Crystal Power Plant would be located at the toe of the dam. It would consist of three 16,000-kilowatt generating units operating under a constant head of about 300 feet. Tailwater elevation at the plant would be about 6,570 feet. The initial energy generation of the plant with all project units in coordinated operation would amount to 244,000,000 kilowatt-hours annually. With ultimate upstream depletions approximately 206,000,000 kilowatt-hours would be produced annually.

Facilities would be constructed to transmit the energy produced and to interconnect the Crystal plant with other power plants.

Access

The dam site can now be reached only by foot. For construction purposes an access road could be built from a point on United States Highway No. 50. This highway parallels the river 5 or 6 miles south of the dam site. The canyon is particularly deep and steep at the dam site and access is quite difficult.

Rights-of-way and Relocation

Right-of-way costs would be low since the reservoir basin is small and confined to the river channel. There are no facilities of any importance which would require relocation.

Geology

The abutments and foundation at the dam site are igneous and metamorphosed intrusive rocks. The rocks are well exposed, massive, and unfractured and are considered of excellent quality to support a dam. Construction materials are limited in the area. Investigations will be made to determine the suitability of crushed aggregate taken from the canyon walls.

Cost Estimates

Estimated costs of the Crystal unit, based on December 1949 prices, are summarized in the table on the following page.

ESTIMATED COSTS OF CRYSTAL UNIT

Feature	Construction costs	Annual costs: Operation and maintenance costs	Annual costs: Replacement costs	Annual costs: Total
Dam and reservoir	$24,200,000	$ 2,000	$ 5,000	$ 7,000
Access facilities	1,300,000			
Construction camp	400,000			
Power plant	5,500,000	105,600	49,000	154,600
Transmission system	6,500,000	90,700	73,200	163,900
Total	$37,900,000	$198,300	$127,200	$325,500

Curecanti Unit

Dam and Reservoir

Blue Mesa Dam, key feature of the Curecanti unit, would be located on the Gunnison River about 3½ miles downstream from the town of Sapinero, Colo. The site for this dam has previously been called the Cottonwood site.

The Blue Mesa Dam would be a concrete, gravity-type structure, rising 475 feet and 510 feet above the river and bedrock foundation, respectively. The crest of the dam would be at elevation 7,640 feet, 5 feet above the maximum water surface elevation. At the crest elevation the distance between the canyon walls is about 1,240 feet.

Curecanti Reservoir formed by the dam would have an initial capacity of 2,500,000 acre-feet, including an active capacity of 2,010,000 acre-feet and an inactive capacity of 490,000 acre-feet. In 200 years silt deposits would reduce the active capacity to 1,979,000 acre-feet and the inactive capacity to 463,000 acre-feet. When filled to capacity, the reservoir would cover 18,200 acres and it would extend about 30 river miles upstream to within about a mile of Gunnison, Colo.

Diversion, spillway, and outlet works. During construction of the dam the river flow would be diverted through a tunnel in the right abutment. The tunnel would provide protection against a flood of 22,500 second-feet. After construction of the dam the diversion tunnel would be plugged and utilized as part of the spillway.

The spillway, which would have a capacity of 48,000 second-feet, would be located in the right abutment and would discharge into an

inclined tunnel leading to the diversion tunnel. Control of the spill would be provided by two 50-foot by 28-foot gates over a crest at elevation 7,607 feet.

Outlet works with a capacity of about 2,000 second-feet would be provided.

Power Features

The power plant would be located at the toe of the dam. It would consist of three 18,000-kilowatt units and would have a total installed capacity of 54,000 kilowatts. The plant would operate under a maximum static head of 470 feet and a mean operating head of about 425 feet. Tailwater elevation at the power plant would be about 7,165 feet. The initial energy generation of the plant with all the project units in coordinated operation would amount to 300,000,000 kilowatt-hours annually. With ultimate upstream depletions approximately 227,000,000 kilowatt-hours would be produced annually.

The necessary transmission facilities would be constructed to distribute the electric energy produced to various load centers and points of interconnection.

Access

United States Highway No. 50, which traverses the reservoir area, would be relocated to provide access to the Blue Mesa Dam site. Colorado State Highway No. 92 now extends to the dam site from a point on United States Highway No. 50 at Sapinero, Colo. Portions of the State Highway and the junction of the State and National highways, however, would be inundated by the reservoir.

Rights-of Way and Relocation

As previously mentioned, United States Highway No. 50 would be relocated to provide access to the dam. The relocated route would cross the river over the dam. At one time, the Denver and Rio Grande Western Railroad operated a narrow gage line through the reservoir area but this line was recently abandoned. Rights-of-way would be required for five small towns which lie within the reservoir area, including Sapinero, Cebolla, Iola, Kezar, and Hierro. The cost of the towns' combined improvements is relatively low.

Geology

Rock structures in the reservoir basin are well consolidated and therefore no appreciable seepage losses are expected. At the dam site

no faulting is noted. Local shear and joint planes do exist but these are not expected to offer significant construction problems. The rocks forming the abutments and foundation at the dam site are of pre-Cambrian granite, gneiss, and schist. The dam site is considered competent to support either a concrete gravity- or arch-type dam.

Five holes have been drilled at the dam site. These have shown a depth of river fill of 15 feet but suggest that the maximum depth may be about 20 feet.

Investigations indicate that there are sufficient quantities of suitable construction materials for either an earth-fill or concrete dam within 11 miles of the dam site. All of the borrow areas are situated along United States Highway No. 50.

Cost Estimates

Estimated costs of the Curecanti unit, based on December 1949 prices, are summarized in the following table.

ESTIMATED COSTS OF CURECANTI UNIT

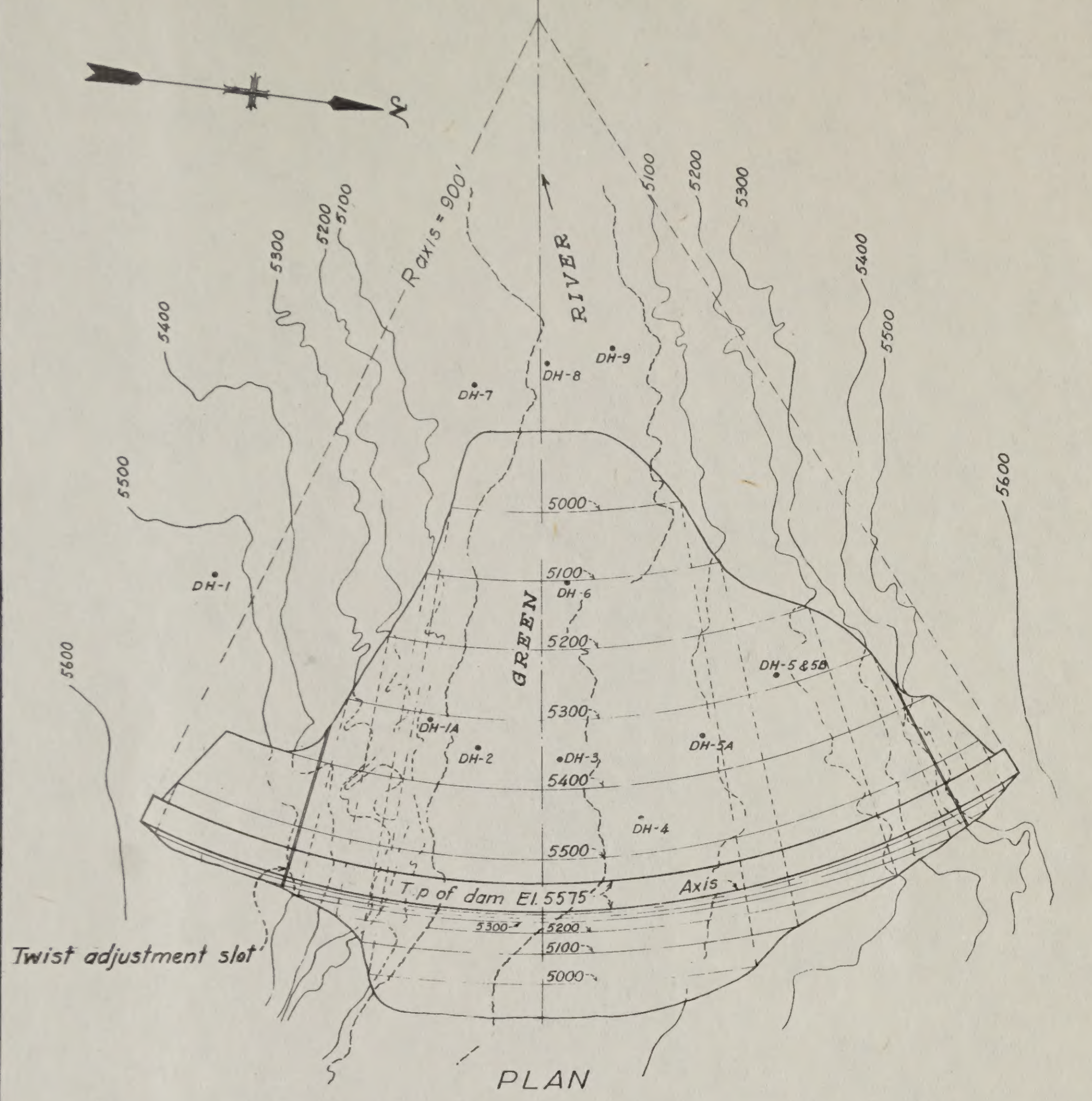
Feature	Construction costs	Annual costs		
		Operation and maintenance costs	Replacement costs	Total
Dam and reservoir	$58,700,000	$ 19,000	$ 12,100	$ 31,100
Highway relocation	7,300,000			
Rights-of-way	700,000			
Construction camp	900,000			
Power plant	5,500,000	112,900	49,600	162,500
Transmission system	7,300,000	102,100	82,400	184,500
Total	$80,400,000	$234,000	$144,100	$378,100

Echo Park Unit

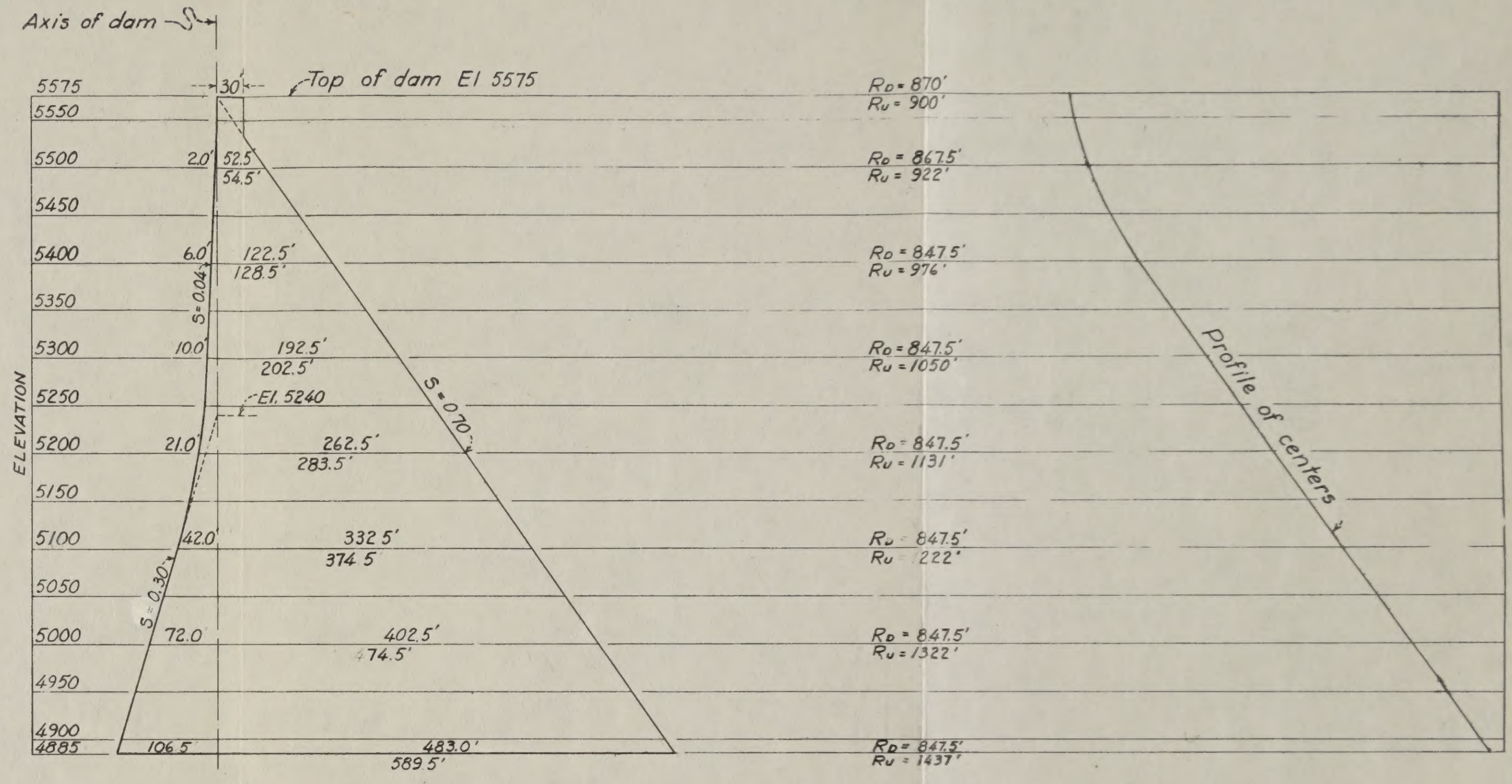
Dam and Reservoir

Echo Park Dam would be located on the Green River about 3 miles east of the Utah-Colorado State line and about 3 miles downstream from the confluence of the Green and Yampa Rivers.

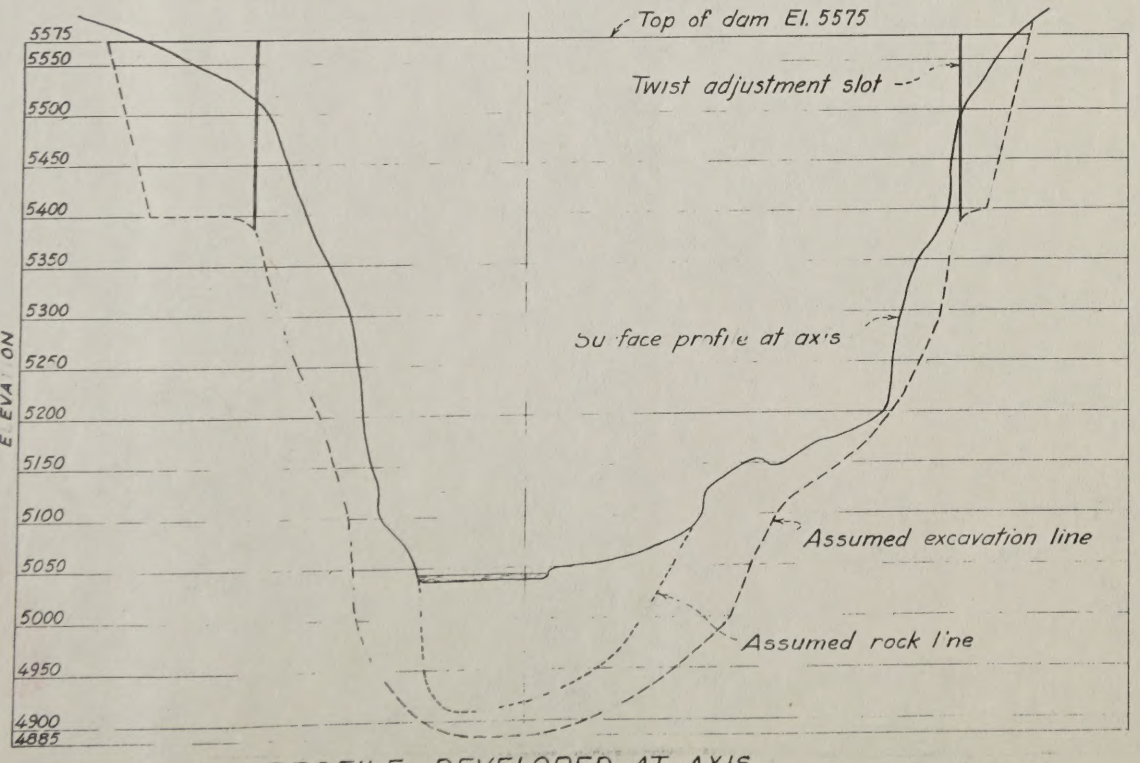
Preliminary designs for Echo Park Dam are shown on the drawings on the following pages.


N
Raxis = 900'
GREEN RIVER
5600
5500
5400
5300
5200
5100
5000
DH-1
DH-2
DH-3
DH-4
DH-5 & 5B
DH-5A
DH-6
DH-7
DH-8
DH-9
DH-1A
Top of dam El. 5575'
Axis
Twist adjustment slot

PLAN

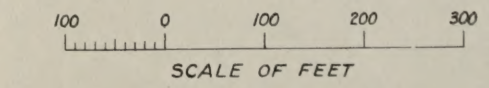

Axis of dam
30'
Top of dam El 5575
ELEVATION
5575
5550
5500
5450
5400
5350
5300
5250
5200
5150
5100
5050
5000
4950
4900
4885
2.0'
52.5'
54.5'
6.0'
122.5'
128.5'
S=0.04
10.0'
192.5'
202.5'
El. 5240
S=0.70
21.0'
262.5'
283.5'
42.0'
332.5'
374.5
S=0.30
72.0
402.5'
474.5'
106.5'
483.0'
589.5'
Ro = 870'
Ru = 900'
Ro = 867.5'
Ru = 922'
Ro = 847.5'
Ru = 976'
Ro = 847.5'
Ru = 1050'
Ro = 847.5'
Ru = 1131'
Ro = 847.5'
Ru = 1222'
Ro = 847.5'
Ru = 1322'
Ro = 847.5'
Ru = 1437'
Profile of centers

MAXIMUM SECTION


Top of dam El. 5575
Twist adjustment slot
Surface profile at axis
Assumed excavation line
Assumed rock line
ELEVATION
5575
5550
5500
5450
5400
5350
5300
5250
5200
5150
5100
5050
5000
4950
4900
4885

PROFILE DEVELOPED AT AXIS

Reference drawings: 3l7-D-11
3l7-D-12


100
0
100
200
300

SCALE OF FEET

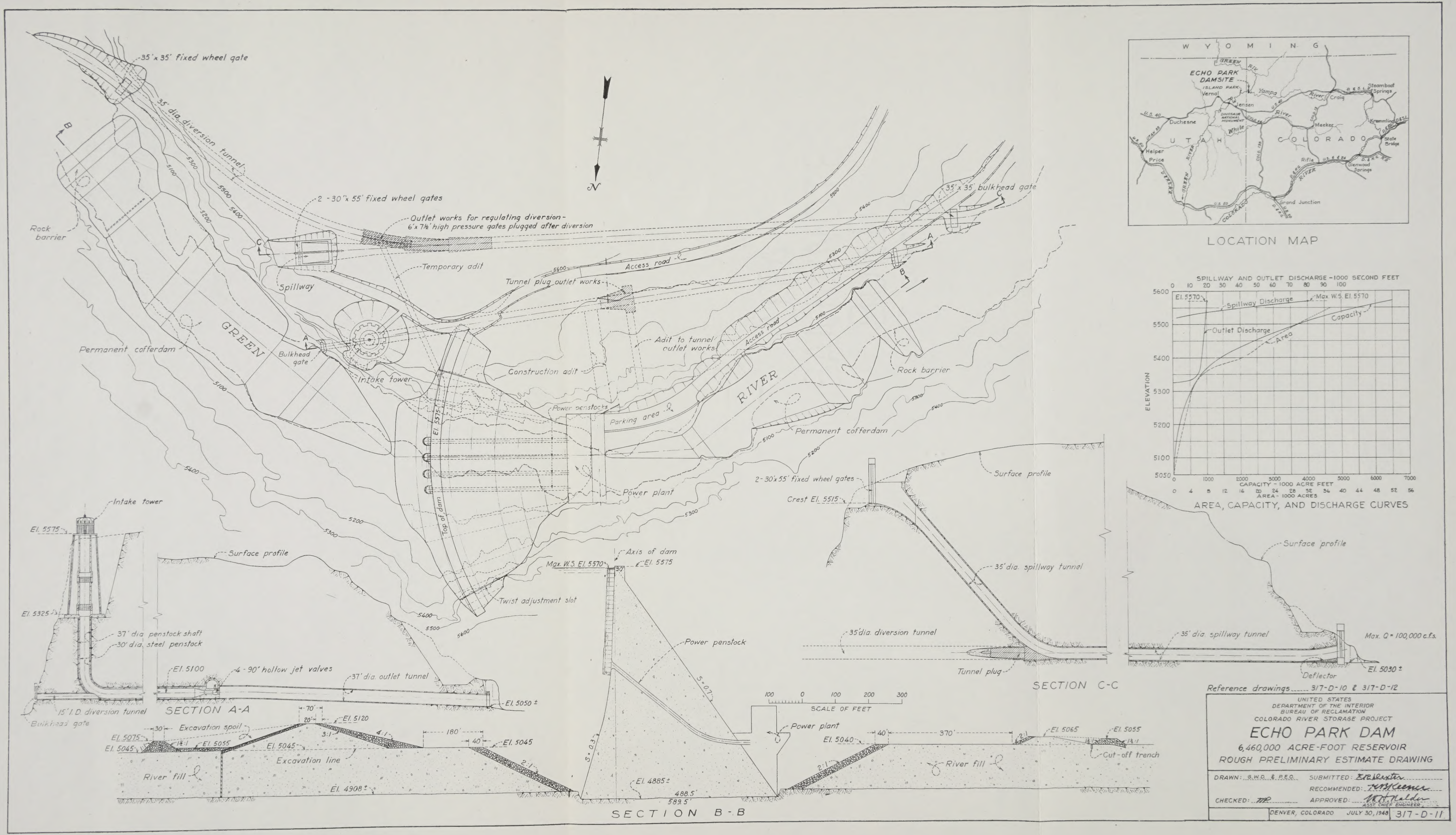
STUDY NO. G-2

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT

ECHO PARK DAM

PLAN, PROFILE, & SECTION
ROUGH PRELIMINARY DESIGN DRAWING

DRAWN G.W.D. & S.W.C. SUBMITTED
TRACED RECOMMENDED K.B. Keener
CHECKED MP APPROVED W.H. Nalder
ASST. CHIEF ENGINEER, CIVIL
DENVER, COLORADO, JULY 30, 1948
317-D-10


35'x 35' fixed wheel gate
35' dia. diversion tunnel
B
N
2 - 30'x 55' fixed wheel gates
Outlet works for regulating diversion - 6'x 7½' high pressure gates plugged after diversion
Rock barrier
C
Temporary adit
Spillway
Tunnel plug outlet works
Access road
5600
5500
5400
5300
5200
5100
35'x 35' bulkhead gate
A
GREEN
RIVER
Permanent cofferdam
Bulkhead gate
Intake tower
Construction adit
Adit to tunnel outlet works
Rock barrier
Power penstocks
Parking area
El. 5575
Top of dam
Power plant
Twist adjustment slot
2-30'x55' fixed wheel gates
Crest El. 5515
Surface profile
35' dia. spillway tunnel
35'dia. diversion tunnel
Tunnel plug
SECTION C-C
35' dia. spillway tunnel
Max. Q = 100,000 c.f.s.
Deflector
El. 5030 ±
Intake tower
El. 5575
El. 5325
37' dia. penstock shaft
30' dia. steel penstock
15' I.D. diversion tunnel
Bulkhead gate
Surface profile
El. 5100
4 - 90" hollow jet valves
37' dia. outlet tunnel
El. 5050 ±
SECTION A-A
Axis of dam
Max. W.S. El. 5570
El. 5575
30'
Power penstock
5 : 0.7
5 : 0.3
El. 4885 ±
488.5'
589.5'
Power plant
100 0 100 200 300
SCALE OF FEET
30'
Excavation spoil
70'
20'
El. 5120
El. 5075
El. 5045
1½:1
El. 5055
El. 5045
3:1
4:1
180'
40'
El. 5045
Excavation line
2:1
River fill
El. 4908 ±
El. 5040
40'
370'
El. 5065
El. 5055
2:1
1½:1
Cut-off trench
River fill
SECTION B-B
WYOMING
GREEN RIV.
ECHO PARK DAMSITE
ISLAND PARK
Vernal
Jensen
Yampa River
Craig
D. & S. L. R.
Steamboat Springs
U.S. 40
Duchesne
DINOSAUR NATIONAL MONUMENT
COLO. 64
River
COLO. 13
Meeker
Kremmling
D&SL
White
UTAH
COLORADO
UTAH 33
U.S. 50
Helper
Price
D. & R.G.W.
GREEN RIVER
COLO. 139
State Bridge
Rifle
U.S. 6 & 24
D. & R.G. R.R.
Glenwood Springs
D. & R.G.
RIVER
U.S. 50
COLORADO
Grand Junction
D. & R.G.
U.S. 50
LOCATION MAP
SPILLWAY AND OUTLET DISCHARGE - 1000 SECOND FEET
0 10 20 30 40 50 60 70 80 90 100
El. 5570
Spillway Discharge
Max. W.S. El. 5570
Capacity
Outlet Discharge
Area
ELEVATION
5600 5500 5400 5300 5200 5100 5050
0 1000 2000 3000 4000 5000 6000 7000
CAPACITY - 1000 ACRE FEET
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56
AREA - 1000 ACRES
AREA, CAPACITY, AND DISCHARGE CURVES

Reference drawings ...... 317-D-10 & 317-D-12

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT

ECHO PARK DAM

6,460,000 ACRE-FOOT RESERVOIR
ROUGH PRELIMINARY ESTIMATE DRAWING

DRAWN: G.W.D. & P.E.O.
SUBMITTED: E.R. Dexter
RECOMMENDED: H.B. Keener
CHECKED: M.P.
APPROVED: W.H. Nalder
ASST. CHIEF ENGINEER

DENVER, COLORADO JULY 30, 1948 317-D-11

Echo Park Dam would be a concrete, curved, gravity-type structure. It would rise 525 feet above the river bed and 690 feet above bedrock. The crest would be at elevation 5,575 feet, 5 feet above the maximum reservoir water surface elevation. The crest length would be 920 feet.

The reservoir formed by the dam would have a total initial capacity of 6,460,000 acre-feet, including an active capacity of 5,460,000 acre-feet and an inactive capacity of 1,000,000 acre-feet. Over a 200-year period silt deposits would reduce the active capacity by about 291,000 acre-feet and the inactive capacity by 247,000 acre-feet. After 200 years the active storage capacity at Echo Park would comprise 20 percent of the total active storage provided by the project. When filled to capacity, the reservoir would have a water surface area of 43,000 acres and it would extend 63 miles up the Green River and 44 miles up the Yampa River. Most of the reservoir basin would be in narrow canyon sections and thus a minimum amount of water would be lost through evaporation. At some later date it may be found desirable to pump water from Echo Park Reservoir for use in the Uinta Basin of Utah.

Diversion, spillway, and outlet works. A concrete-lined tunnel would be constructed through the left abutment to divert the river flow around the dam site during construction. This tunnel would provide protection against a flood flow of 27,500 second-feet. After construction of the dam the diversion tunnel would be plugged and utilized as part of the spillway.

The spillway would have a capacity of 81,500 second-feet. It would discharge water through an inclined tunnel in the left abutment leading to the diversion tunnel which, in turn, would carry the water back to the river channel on the downstream side of the dam. The spill would be controlled by two 30-foot by 55-foot Stoney gates over a crest at elevation 5,515 feet.

An outlet works, consisting of an intake tower of the type constructed at Hoover Dam and a tunnel through the left canyon wall, would discharge 20,000 second-feet with the reservoir at maximum water surface elevation. A temporary outlet valve would be installed in the diversion tunnel plug to control the river flow until the water level reaches the sill of the permanent outlet works at elevation 5,325 feet.

Power Features

Echo Park Power Plant would be located at the toe of the dam. The plant would consist of four 50,000-kilowatt units and would have a total installed capacity of 200,000 kilowatts. Each generating unit would

receive water through an individual penstock passing through the dam. Each penstock would have its own trashrack and gate structure. Initially, with all the project units in coordinated operation, the plant would produce 995,000,000 kilowatt-hours annually. With ultimate upstream depletions approximately 677,000,000 kilowatt-hours would be produced annually. The plant would operate under a maximum static head of 520 feet and a mean operating head of about 475 feet. Tailwater elevation at the power plant would be about 5,050 feet.

The necessary transmission facilities would be constructed to deliver the electric energy produced to load centers and points of interconnection.

Geology

Geological explorations of the Echo Park Dam and Reservoir sites were made in 1940 by the Bureau of Reclamation. The investigations showed the sites to be suitable for the features contemplated. The foundation and lower part of the abutment walls would be in the Uinta quartzitic sandstone. The upper part of the abutments would be in the Lodore sandstone. Both of these rocks possess satisfactory characteristics for the construction of a high concrete dam. River fill material extends to a maximum depth of 148 feet. Considerable jointing was found in the dam site vicinity, but no faults were found. A reasonable grouting program should effectively seal all paths of seepage.

Deposits of concrete aggregate lie in the Island Park area 8 to 10 miles downstream from the dam site. These deposits have been extensively investigated, and tests made on representative samples have shown aggregate to be of satisfactory quality for use in the construction of the dam. There is, however, a shortage of aggregate in sizes in excess of 3 inches in diameter. Coarse aggregate, however, could be quarried from limestone formations near the dam site. Investigations will be made of other construction material sources as a part of the preconstruction studies.

Access

Preliminary investigations have been completed for an access road that would extend from Vernal, Utah, on United States Highway No. 40 to Island Park and that would then continue along the south side of the Green River through Whirlpool Canyon to the dam site. Other routes will be studied during the preconstruction surveys. In the investigations of alternative routes, consideration should be given to the desirability of routing the road by the construction camp and deposits of construction materials. Consideration should also be given to the possibility of locating the road so that it would provide access to facilities of the

Split Mountain unit and permit at least part of the Echo Park construction camp to be used for the Split Mountain unit.

Rights-of-way and Relocation

Echo Park Reservoir would occupy all of the Yampa and Green River channels within the Dinosaur National Monument upstream from the dam site. The original 80 acres of the monument, the area which includes the fossil deposits and the monument headquarters, would not be affected by the reservoir or any of the construction features. The reservoir, however, would open to the public an area now almost inaccessible. Rights-of-way for the reservoir would have to be acquired on about 17,000 acres of private or State-owned lands that lie within the exterior boundaries of the monument. Of the 17,000 acres less than 2,000 acres are irrigated or otherwise developed for agricultural use. Most of the developed lands are used for pasture or hay production while the undeveloped land is used principally for grazing. The upper portion of the reservoir on the Green River would extend about 8 miles into the Ashley National Forest. Only rights-of-way for privately owned land in this area would be required.

A few mining claims in the reservoir area have been renewed since 1940, but no mines are operating. No producing oil wells are located in the area. No facilities within the area would require relocation.

Cost Estimates

Cost estimates for the Echo Park unit, based on December 1949 prices, are summarized in the following table.

ESTIMATED COSTS OF ECHO PARK UNIT

Feature	Construction costs	Annual costs		
		Operation and maintenance costs	Replacement costs	Total
Dam and reservoir	$106,700,000	$ 31,000	$ 21,900	$ 52,900
Access road	10,000,000			
Rights-of-way	100,000			
Construction camp	1,800,000			
Power plant	19,800,000	280,000	183,200	463,200
Transmission system	27,000,000	378,000	305,100	683,100
Total	$165,400,000	$689,000	$510,200	$1,199,200

Flaming Gorge Unit

Dam and Reservoir

Ashley Dam, key feature of the Flaming Gorge unit, would be located in northeastern Utah about 32 air miles north of Vernal, Utah. It would be located on the Green River 290 river miles upstream from Green River, Utah, and about 32 river miles downstream from the Utah-Wyoming State line.

Ashley Dam would be a concrete, gravity-type structure, rising 440 feet above the river and 491 feet above its bedrock foundation. The crest would be at elevation 6,045 feet, 5 feet above the maximum water surface elevation. The distance between the canyon walls at the crest elevation is about 900 feet.

Flaming Gorge Reservoir formed by the dam would have a total initial capacity of 3,940,000 acre-feet, including an active capacity of 2,950,000 acre-feet and an inactive capacity of 990,000 acre-feet. In 200 years silt deposits would reduce the active capacity to 2,550,000 acre-feet and the inactive capacity to 11,000 acre-feet. When filled to capacity, the reservoir would have a water surface area of 40,800 acres and would extend 91 miles upstream, to within 3 or 4 miles of the town of Green River, Wyo.

Diversion, spillway, and outlet works. During the construction period water would be diverted around the dam site through a tunnel in the right abutment. The tunnel would have a capacity of 20,000 second-feet.

The spillway would discharge into an inclined tunnel leading to the diversion tunnel. It would have a capacity of 85,000 second-feet. Control of the spill would be provided by three 22-foot by 50-foot Stoney gates over a crest at elevation 5,990 feet.

Outlet works of 5,000 second-foot capacity would be provided through the dam.

Power Features

The power plant, located at the toe of the dam, would consist of three units with a total installed capacity of 72,000 kilowatts. The plant would operate under a maximum head of 435 feet and a mean head of about 395 feet. Initially, with all the project units in coordinated operation, 337,000,000 kilowatt-hours would be produced annually. After all stream flow depletions were made by future upstream developments,

about 105,000,000 kilowatt-hours would be produced annually. Estimated tailwater elevation at the power plant would be 5,605 feet.

The necessary transmission facilities would be constructed.

Access

Utah State Highway No. 44 extends 40 miles from Vernal, Utah, to a point about 7 miles from the dam site. From the highway a mountain road, about 6 miles long, and a foot trail, about 1 mile long, extend to the site. Improved roads also reach south from Lyman and Green River to the head of the mountain road. Either the route from Utah or the one from Wyoming could be used for access to the dam during the construction period. New construction would be required over the greater part of either route. Rail facilities are available at Green River, Wyo., for the approach from the north and at Heber, Utah, or Craig, Colo., for the approach from the south.

Rights-of-way and Relocation

The lower portion of the reservoir basin lies in the Ashley National Forest. Only small right-of-way costs in this area would be required The upper end of the reservoir would reach nearly to Green River, Wyo., but would not interfere with any of the city's improvements. A portion of a secondary road crossing Blacks Fork between Green River, Wyo., and Manila, Utah, would have to be relocated. No other major work is expected in connection with relocating facilities in the reservoir area.

Geology

The rock at this dam site belongs to the Uinta formation and consists of hard, massive, purplish-red quartzose sandstone. Bedding planes are from 1 to 20 feet apart with some minor shale partings. The geological characteristics at the dam site are satisfactory for the type of dam contemplated. A fairly prominent system of joints cuts across the river at the axis. Although some of the joints are open, they can be successfully sealed with grouting. Drilling in the river bottom shows the maximum depth of river fill to be 31 feet.

One fairly large gravel deposit, located near the mouth of Gorge Creek 7 or 8 miles downstream from the dam axis, is a possible source of construction materials. Other deposits are in the vicinity but will require further investigation.

Cost Estimates

Estimated costs of the Flaming Gorge unit, based on December 1949 prices, are summarized in the following table.

ESTIMATED COSTS OF FLAMING GORGE UNIT

Feature	Construction costs	Annual costs		
		Operation and maintenance costs	Replacement costs	Total
Dam and reservoir	$57,700,000	$ 23,600	$ 11,800	$ 35,400
Access facilities	6,500,000			
Rights-of-way	200,000			
Construction camp	900,000			
Power plant	7,700,000	133,900	68,700	202,600
Transmission system	9,700,000	136,100	109,800	245,900
Total	$82,700,000	$293,600	$190,300	$483,900

Glen Canyon Unit

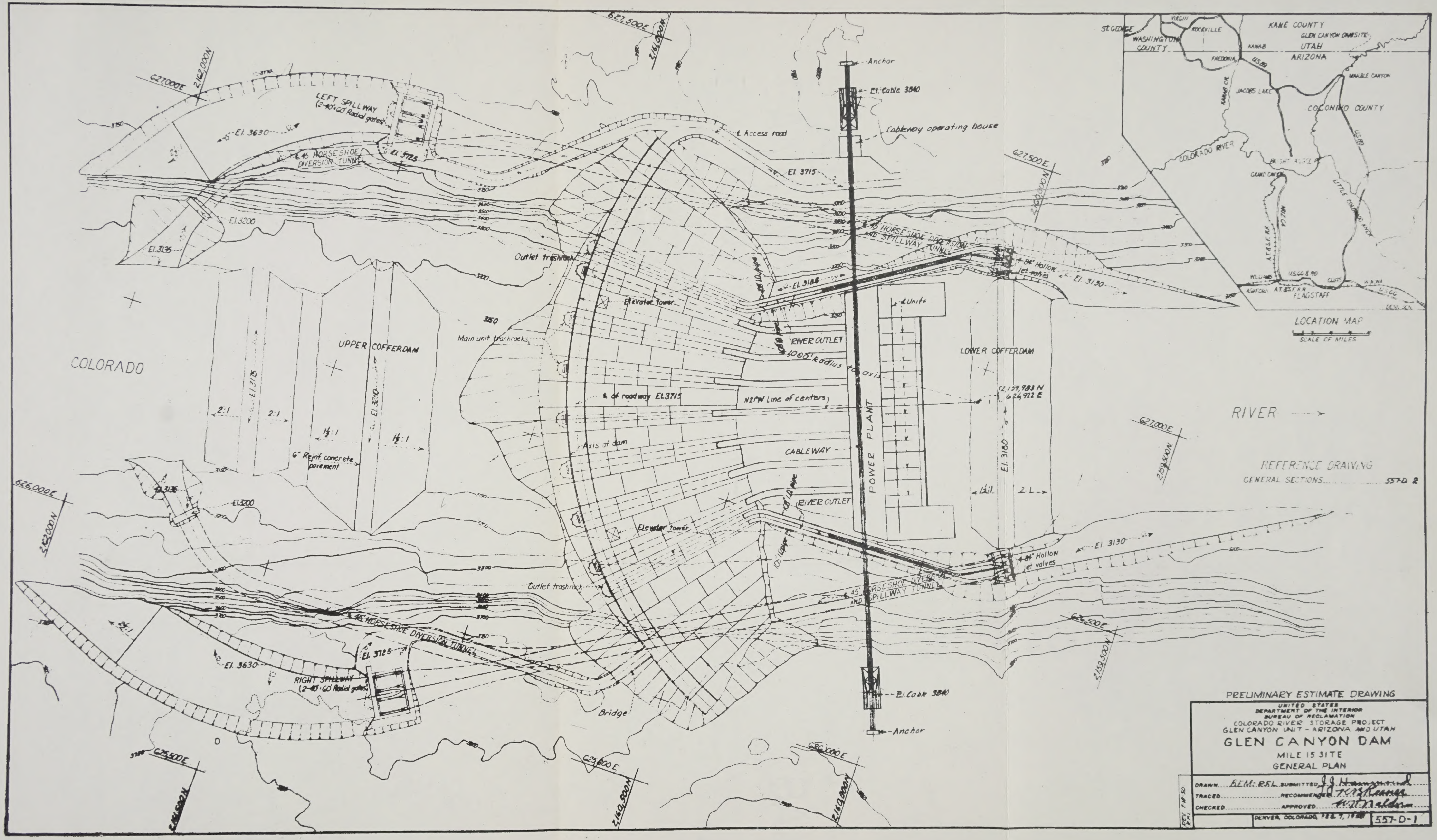
Dam and Reservoir

The Glen Canyon Dam site is located on the Colorado River in northern Arizona, about 13 river miles downstream from the Utah-Arizona State line and 15 miles upstream from Lees Ferry.

Preliminary design drawings for the Glen Canyon Dam are shown on the following pages.

The dam would be a concrete, ~~curved, gravity~~ Arch-type structure, rising 580 feet above the river and 700 feet above the bedrock foundation. The crest would be at elevation 3,715 feet. Ten feet of surcharge, amounting to about 2,000,000 acre-feet of capacity, would be provided above the normal water surface. Five feet of freeboard would be provided above the flood storage. The crest length of the dam would be about 1,400 feet.

The reservoir would have an initial capacity of 26,000,000 acre-feet, including 20,000,000 acre-feet of active capacity and 6,000,000 acre-feet of inactive capacity. In 200 years silt deposits would reduce the active capacity to 10,455,000 acre-feet and would completely fill the inactive storage pool. The reservoir would have a maximum water surface area of about 153,000 acres. When filled to capacity, it would extend about 186 river miles up the Colorado River, nearly to the mouth of the Green River, and 71 river miles up the San Juan River.


LEFT SPILLWAY (2-40'x60' Radial gates)
El. 3630
45' HORSESHOE DIVERSION TUNNEL
El. 3725
Access road
El. 3715
Anchor
El. Cable 3840
Cableway operating house
El. 3200
El. 3135
Outlet trashrack
Elevator tower
Main unit trashracks
UPPER COFFERDAM
El. 3175
El. 3200
2:1
½:1
6" Reinf. concrete pavement
COLORADO
RIVER
45' HORSESHOE DIVERSION AND SPILLWAY TUNNEL
4-84" Hollow jet valves
El. 3130
El. 3188
Units
RIVER OUTLET
1000' Radius to axis
℄ of roadway El. 3715
N21°W Line of centers
Axis of dam
CABLEWAY
POWER PLANT
LOWER COFFERDAM
2,159,983 N
626,922 E
El. 3180
108" I.D. pipe
Bridge
RIGHT SPILLWAY (2-40'x60' Radial gates)
626,000 E
625,500 E
626,500 E
627,000 E
627,500 E
2,159,500 N
2,160,000 N
2,160,500 N
2,161,000 N
LOCATION MAP
SCALE OF MILES
ST. GEORGE
WASHINGTON COUNTY
VIRGIN
ROCKVILLE
KANE COUNTY
GLEN CANYON DAMSITE
KANAB
UTAH
ARIZONA
FREDONIA
US 89
KANAB CR.
JACOBS LAKE
MARBLE CANYON
COCONINO COUNTY
COLORADO RIVER
BRIGHT ANGEL PT.
GRAND CANYON
LITTLE COLORADO RIVER
A.T.&S.F. R.R.
WILLIAMS
ASHFORK
U.S. 66 & 89
CLIFFS
FLAGSTAFF
WINONA
U.S. 66
DENNISON

REFERENCE DRAWING
GENERAL SECTIONS........................557-D 2

PRELIMINARY ESTIMATE DRAWING

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GLEN CANYON UNIT - ARIZONA AND UTAH

GLEN CANYON DAM

MILE 15 SITE
GENERAL PLAN

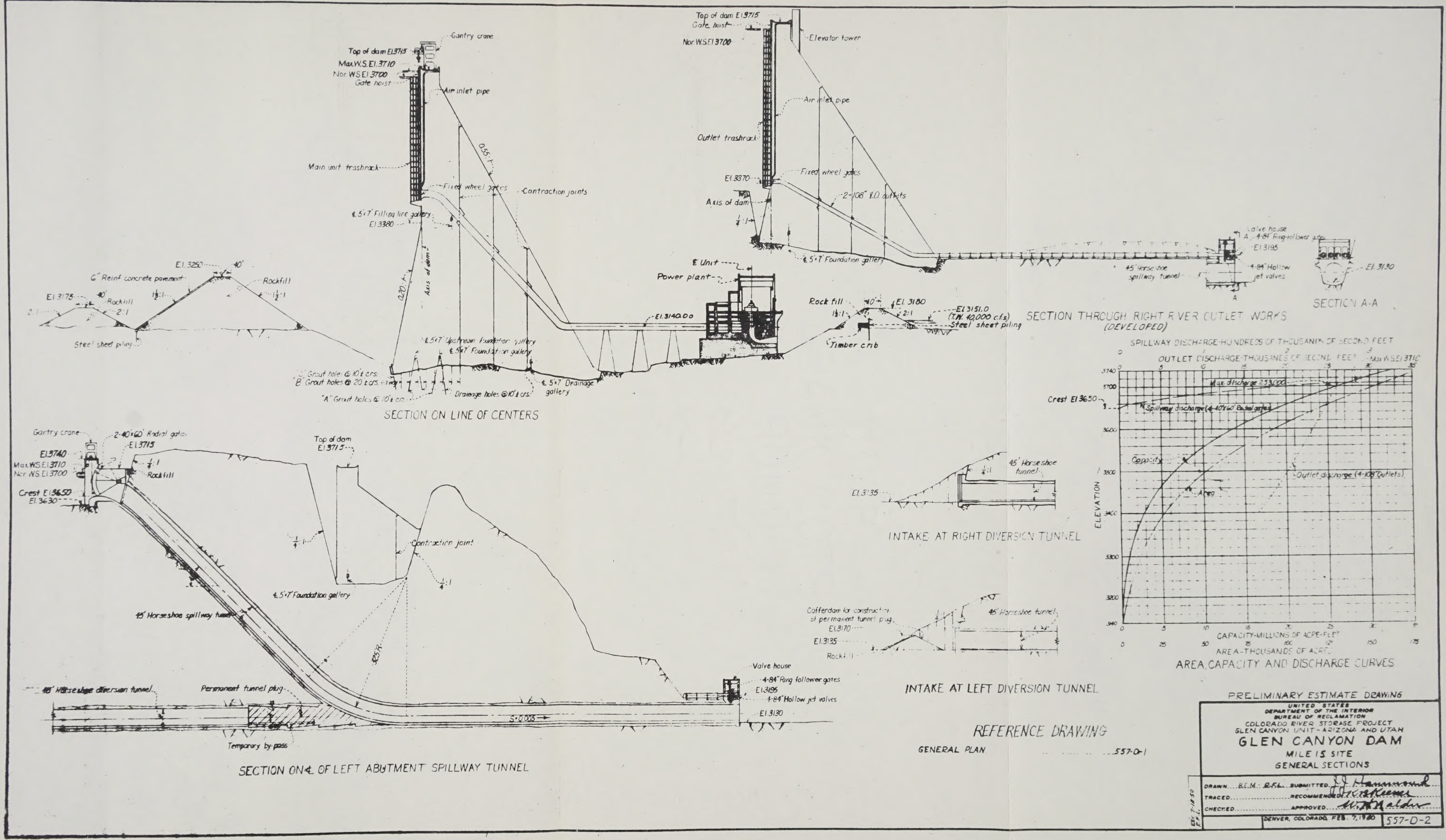
DRAWN... BEM: RFL SUBMITTED J. J. Hammond
TRACED......... RECOMMENDED J. H. Kenner
CHECKED......... APPROVED W. H. Nalder

REV. 7-18-50 RFL

DENVER, COLORADO, FEB. 7, 1950 557-D-1

Form No. X-D-3776

U.B.N.,S.L.C.,U. 500 -8-50


Gantry crane
Top of dam El.3715
Max.W.S.El.3710
Nor.W.S.El.3700
Gate hoist
Air inlet pipe
0.55:1
Main unit trashrack
Fixed wheel gates
Contraction joints
℄ 5'×7' Filling line gallery
El.3380
0.20:1
Axis of dam
E1.3250
40'
6" Reinf. concrete pavement
Rockfill
1½:1
El.3175
40'
Rockfill
2:1
2:1
Steel sheet piling
℄ Unit
Power plant
El.3140.00
Rock fill
40'
El.3180
1½:1
2:1
El.3151.0
(T.W. 40,000 c.f.s.)
Steel sheet piling
Timber crib
℄ 5'×7' Upstream foundation gallery
℄ 5'×7' Foundation gallery
"C" Grout holes @ 10' ctrs.
"B" Grout holes @ 20' ctrs.
"A" Grout holes @ 10' ctrs.
Drainage holes @ 10' ctrs.
℄ 5'×7' Drainage gallery
Top of dam El.3715
Gate hoist
Nor.W.S.El.3700
Elevator tower
Air inlet pipe
Outlet trashrack
El.3370
Fixed wheel gates
Axis of dam
2-108" I.D. outlets
¼:1
℄ 5'×7' Foundation gallery
45' Horseshoe spillway tunnel
Valve house
A
4-84" Ring-follower gates
El.3195
4-84" Hollow jet valves
A
El.3130
Gantry crane
2-40'×60' Radial gates
El.3715
El.3740
Max.W.S.El.3710
Nor.W.S.El.3700
¼:1
Rockfill
Crest El.3650
El.3630
Top of dam
El.3715
¼:1
Contraction joint
¼:1
℄ 5'×7' Foundation gallery
45' Horseshoe spillway tunnel
325'R.
45' Horseshoe diversion tunnel
Permanent tunnel plug
Temporary by-pass
S=0.005
Valve house
4-84" Ring follower gates
El.3195
4-84" Hollow jet valves
El.3130
¼:1
45' Horseshoe tunnel
El.3135
Cofferdam for construction of permanent tunnel plug
El.3170
El.3135
Rockfill
45' Horseshoe tunnel
SPILLWAY DISCHARGE-HUNDREDS OF THOUSANDS OF SECOND FEET
0
1
2
3
OUTLET DISCHARGE-THOUSANDS OF SECOND FEET
Max.W.S.El.3710
0
5
10
15
20
25
30
35
3740
3700
3600
3500
3400
3300
3200
3140
Crest El.3650
Max. discharge 253,000
Spillway discharge (4-40'×60' Radial gates)
Capacity
Outlet discharge (4-108" Outlets)
Area
ELEVATION
0
5
10
15
20
25
30
35
CAPACITY-MILLIONS OF ACRE-FEET
0
25
50
75
100
125
150
175
AREA-THOUSANDS OF ACRES

SECTION ON LINE OF CENTERS

SECTION THROUGH RIGHT RIVER OUTLET WORKS
(DEVELOPED)

SECTION A-A

SECTION ON ℄ OF LEFT ABUTMENT SPILLWAY TUNNEL

INTAKE AT RIGHT DIVERSION TUNNEL

INTAKE AT LEFT DIVERSION TUNNEL

AREA, CAPACITY AND DISCHARGE CURVES

REFERENCE DRAWING

GENERAL PLAN 557-D-1

PRELIMINARY ESTIMATE DRAWING

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
GLEN CANYON UNIT - ARIZONA AND UTAH
GLEN CANYON DAM
MILE 15 SITE
GENERAL SECTIONS

DRAWN....B.E.M.: R.F.L....SUBMITTED....J. J. Hammond
TRACED....RECOMMENDED....K. B. Keener
CHECKED....APPROVED....W. H. Nalder
DENVER, COLORADO, FEB. 7, 1950
557-D-2

REV. 7-18-50 R.F.L.

U.B.N.,S.L.C.,U. 500 -8-50

Exam No. X-D-3776.

Diversion, spillway, and outlet works. During the construction period the river flow would be diverted around the dam site through a tunnel in each abutment. The tunnels would provide protection against a flood flow of 120,000 second-feet, a flow slightly higher than the highest discharge recorded during the period 1923 to 1945.

Two spillways, one in each abutment, would be provided to discharge a total of 253,000 second-feet at a water surface elevation of 3,710 feet. The spillways would be identical. Each would discharge into an inclined tunnel leading to a diversion tunnel. Control of each spillway would be provided by two 40-foot by 60-foot radial gates over a crest at elevation 3,650 feet.

The outlet works would have a capacity of 20,000 second-feet with the reservoir water surface at elevation 3,490 feet.

Power Features

Glen Canyon Power Plant would be located near the toe of the dam. The plant, consisting of seven generating units, would have a total installed capacity of 800,000 kilowatts. The plant would operate under a mean head of about 480 feet. Initially, with all the project units in coordinated operation, it would produce about 4,337,000,000 kilowatt-hours annually. With ultimate stream flow depletions, it would produce approximately 2,992,000,000 kilowatt-hours annually. Minimum and maximum tailwater elevations at the plant would be 3,135 feet and 3,181 feet, respectively.

The necessary transmission facilities would be constructed to distribute the electric energy to load centers or points of interconnection.

Geology

The Glen Canyon site is geologically favorable for a high concrete dam. At the site the sides of the canyon rise abruptly from the river bed in nearly vertical walls 650 feet high. The rock forming the abutments and the foundation is the massive Navajo sandstone of Jurassic age. This massive formation is a medium- to fine-grained sandstone, buff to red in color. The rock is remarkably free of structural defects. No folds are found in the dam site area, and the massive sandstone lies in a nearly horizontal position except for a slight dip upstream into the left abutment.

Twenty-eight holes have been drilled at the Glen Canyon site. The rock conditions were shown by the exploratory work to be generally satisfactory.

Overburden in the river channel consists of sand, silt, gravel, and a few medium-sized boulders and ranges in depth from a few feet near the canyon wall to 110 feet near the center of the river bed.

Construction materials of satisfactory quality and adequate quantity can be obtained from deposits in Wahweap Creek about 7 miles northwest of the dam site.

Access

The dam site can now be reached over an ungraded road, which extends about 7 miles to Lees Ferry from a point near Marble Canyon Lodge on United States Highway No. 89, and then by a fairly good horse trail, which extends about 15 miles from Lees Ferry to the dam site. A highway would be built from a point near the Navajo Bridge to the dam site on the east side of the river. A highway could be built to the west side of the dam site from a point on Highway No. 89 south of Kanab, Utah. It may be desirable after construction of the dam to connect these two roads using the dam as a bridge, thus forming a loop or alternate highway to the present Highway 89.

Rights-of-Way and Relocation

No improvements nor improved lands of any consequence are in the reservoir area, and no major facilities would require relocation. A large portion of the reservoir basin, however, lies in the Navajo Indian Reservation.

Cost Estimates

Estimated costs of the Glen Canyon unit, based on December 1949 prices, are summarized in the following table.

ESTIMATED COSTS OF GLEN CANYON UNIT

Feature	Construction costs	Annual costs		
		Operation and maintenance costs	Replacement costs	Total
Dam and reservoir	$148,500,000	$ 63,000	30,500	93,500
Access facilities	27,000,000			
Rights-of-way	400,000			
Construction camp	4,200,000			
Power plant	75,800,000	864,000	738,700	1,602,700
Transmission system	108,000,000	1,512,000	1,220,400	2,732,400
Total	$363,900,000	$2,439,000	$1,989,600	$4,428,600

Gray Canyon Unit

Dam and Reservoir

Gray Canyon Dam would be located in Utah on the Green River about 22 river miles upstream from Green River, Utah. The site, formerly called Rattlesnake site, is about 4 miles upstream from the mouth of the Price River and immediately downstream from the mouth of Rattlesnake Creek.

The dam would be a concrete, gravity-type structure, rising 445 feet above the river and 575 feet above the assumed bedrock foundation. The crest would be at elevation 4,595 feet, 5 feet over the maximum water surface elevation. At the crest elevation the distance between the canyon walls is about 2,100 feet.

The reservoir formed by the dam would have an initial capacity of 2,000,000 acre-feet, including an active capacity of 1,390,000 acre-feet and an inactive capacity of 610,000 acre-feet. In 200 years silt deposits would reduce the active capacity to 698,000 acre-feet and would completely fill the inactive storage pool. When filled to capacity the reservoir would have a water surface area of 10,750 acres and it would extend about 53 river miles up the Green River. The narrow canyon section would confine the reservoir to a maximum width of about half a mile.

Diversion, spillway, and outlet works. During construction of the dam the river flow would be diverted through two tunnels, one on each side of the canyon. The tunnels would have a combined capacity of 100,000 second-feet.

A gate-controlled spillway of 95,000 second-foot capacity would be provided on each side of the canyon. Each of the spillways would discharge through an inclined tunnel leading to a diversion tunnel. Control of each spillway would be provided by three 20-foot by 60-foot gates over a crest at elevation 4,530 feet.

River outlet works of 10,000 second-foot capacity would be provided through the dam.

Power Features

Gray Canyon Power Plant would be located at the toe of the dam. It would consist of four units, each with a capacity of about 52,500 kilowatts, and thus would have a total installed capacity of 210,000 kilowatts. It would operate under a mean head of about 400 feet and a maximum head of 440 feet. Initially, with all the project units in coordinated

operation, the plant would produce more than 1,303,000,000 kilowatt-hours annually. With ultimate upstream depletions, it would produce about 826,000,000 kilowatt-hours annually. Tailwater elevation at the power plant would be 4,150 feet.

Besides the power plant, the power features would include the necessary transmission facilities to distribute the electric energy produced to the various load centers and points of interconnection.

Access

An unimproved road, heading north at Green River, Utah, extends approximately 12 miles along the east side of Green River to a point about 10 miles from the dam site. For access purposes a highway could be constructed along the route of the existing road and extended as necessary to the dam site. The road extension would be through a canyon section but construction is not expected to be particularly difficult. A railhead could be established at Green River.

Rights-of-Way and Relocation

There are no facilities requiring relocation within the reservoir area. With the exception of one ranch, all of the area consists of barren canyon lands. Lands in the area on the east side of the river are in the Hill Creek Extension of the Uinta and Ouray Indian Reservation.

Geology

Because of geologic conditions at the Gray Canyon site, special measures would be required to insure a stable dam. Bedrock at the dam site is a black sandy shale that grades in depth to a clay shale. The abutments are vertical cliffs of Mesaverde sandstone, a hard, gray, but somewhat friable rock. A coal seam, 2 to 5 feet thick, lies about 50 feet above the stream level. The strata dip very slightly upstream. No drilling has been done at the site but the depth of river fill material is variously estimated up to 100 feet.

The only construction materials near the site are the Mesaverde sandstone, which would make fairly good concrete aggregate, and sand and gravel found on several bars along the river. Other materials will probably have to be brought in from the vicinity of Green River, Utah, about 20 miles away.

Cost Estimates

Estimated costs of the Gray Canyon unit, based on December 1949 prices, are summarized in the table on the following page.

ESTIMATED COSTS OF GRAY CANYON UNIT

Feature	Construction costs	Annual costs		
		Operation and maintenance costs	Replacement costs	Total
Dam and reservoir	$126,400,000	$ 16,600	$ 26,000	$ 42,600
Access facilities	1,600,000			
Construction camp	2,000,000			
Power plant	20,000,000	294,000	185,300	479,300
Transmission system	28,400,000	397,000	320,400	717,400
Total	$178,400,00	$707,600	$531,700	$1,239,300

Navajo Unit

Dam and Reservoir

Navajo Dam site is located on the San Juan River in northwestern New Mexico about 19.5 river miles upstream from the small town of Blanco, N. Mex., and 34 miles east of Farmington, N. Mex. It is about 3.5 miles downstream from the confluence of the Pine and San Juan Rivers.

The dam would be a rolled, earth-fill embankment. It would rise 335 feet above stream bed and by means of a cut-off trench would be extended an additional 25 feet to bedrock. The structure would be about 3,280 feet long at the crest. The crest would be at elevation 6,060 feet, 10 feet above the normal water surface elevation. The dam would contain 17,000,000 cubic yards of earth and rock fill.

Initially Navajo Reservoir would have a total capacity of 1,200,000 acre-feet, including an active capacity of 1,050,000 acre-feet and an inactive capacity of 150,000 acre-feet. In 200 years silt deposits would reduce the active capacity to 734,000 acre-feet and the inactive capacity to 33,000 acre-feet. When filled to capacity, the reservoir would have a water surface area of about 10,800 acres and it would extend about 33 miles up the San Juan River, to a point about 3.5 miles beyond the town of Arboles, Colo.

Diversion, spillway, and outlet works. During the construction period the river flow would be diverted through a tunnel in the right abutment. The tunnel would discharge a maximum of 20,000 second-feet.

An open channel spillway, with a capacity of 175,000 second-feet, would be located on the right abutment. The spill would be controlled

Navajo Unit

by four 25-foot by 87½-foot gates over a crest at elevation 6,025 feet. Outlet works, with a capacity of 3,000 second feet, would be installed in the diversion tunnel in the right abutment.

Power Features

Navajo Power Plant would be located at the toe of the dam. It would consist of three 10,000-kilowatt units and thus would have a total installed capacity of 30,000 kilowatts. The plant would operate under a maximum head of 325 feet and a mean head of 275 feet. Initially, with all the project units in coordinated operation, the plant would produce 157,000,000 kilowatt-hours annually. Ultimately, after all upstream water developments are made, it would produce 32,000,000 kilowatt-hours annually. The estimated tailwater elevation of the power plant would be the present river elevation of 5,725 feet.

The necessary transmission facilities would be constructed to deliver the electric energy produced to load centers and points of interconnection.

Access

New Mexico State Highway No. 44 is the paved highway nearest the Navajo site. It passes through Bloomfield approximately 26 miles from the site. A narrow gage line of the Denver and Rio Grande Western Railroad passes through Aztec, N. Mex., 35 miles from the site. The nearest standard gage railhead is at Gallup, N. Mex., 138 miles from Bloomfield and 164 miles from the dam site.

The highways from both Aztec and Gallup to Bloomfield are paved and the bridges are capable of handling heavy trucking. From Bloomfield to the dam site the roads would have to be improved or rebuilt to accommodate heavy trucking.

Rights-of Way and Relocation

A portion of the Denver and Rio Grande Western Railroad narrow gage line between Antonito and Durango, Colo., would have to be relocated. Sections of Colorado State Highways Nos. 151 and 172 would also require relocation. The roads consist of second class or unimproved sections.

The major right-of-way costs involved would be in obtaining the land and improvements of the town of Arboles.

Geology

The rock at the dam site is principally sandstone with minor beds of shale. It belongs to the Wasatch formation. The rock is moderately hard, fairly massive, and is considered completely adequate to support a dam of the height contemplated. Drilling at the site showed the rock to be reasonably tight with no unfavorable conditions. The maximum depth of overburden in the river channel is 34 feet. Except for riprap, suitable construction materials can be found in the area. Riprap would have to be brought in from a distance of 80 or 90 miles.

Cost Estimates

Estimated costs of the Navajo unit, based on December 1949 prices, are summarized in the following table.

ESTIMATED COSTS OF NAVAJO UNIT

		Annual costs		
Feature	Construction costs	Operation and maintenance costs	Replacement costs	Total
Dam and reservoir	$49,400,000	$ 13,000	$10,100	$ 23,100
Access facilities	1,300,000			
Rights-of-way and relocation	1,800,000			
Construction camp	700,000			
Power plant	5,800,000	82,500	42,900	125,400
Transmission system	4,000,000	56,700	45,800	102,500
Total	$63,000,000	$152,200	$98,800	$251,000

Split Mountain Unit

Dam and Reservoir

Split Mountain Dam would be located on the Green River in Uintah County, northeastern Utah, about 14 air miles east of Vernal Utah, and about 2 miles from the headquarters of the Dinosaur National Monument. It would be near the lower end of Split Mountain Canyon and 201 river miles upstream from Green River, Utah. Split Mountain Reservoir would extend upstream to the base of the potential Echo Park Dam.

Split Mountain Dam would be a concrete, gravity-type structure, rising 245 feet above the river and 305 feet above the assumed bedrock foundation. The crest would be at elevation 5,055 feet, 5 feet above the maximum water surface elevation. At the crest elevation the distance between canyon walls is about 990 feet.

Split Mountain Reservoir would have a total capacity of 335,000 acre-feet. It would serve to maintain a power head and would provide regulation only for the daily or hourly releases from the Echo Park unit. Since the reservoir would provide no long-time river regulation nor irrigation storage, its entire capacity is considered inactive. Because of its location below Echo Park Reservoir, Split Mountain Reservoir would not receive significant quantities of sediment. The maximum water surface elevation of Split Mountain Reservoir would not exceed 5,050 feet, the tailwater elevation of Echo Park Power Plant. When full, the reservoir would cover about 4,250 acres and would extend about 21 river miles upstream to the base of Echo Park Dam.

Diversion, spillway, and outlet works. During the construction period the river flow would be diverted around Split Mountain Dam site by an open flume with a capacity of 35,000 second-feet.

The spillway would be a controlled overflow section with a capacity of 112,000 second-feet. Its crest would be at elevation 5,028 feet. The spill would be controlled by three 100-foot by 22-foot gates.

The river outlet works would have a capacity 8,000 second-feet. They would discharge into the spillway.

Power Features

Split Mountain Power Plant would be located about 12 river miles downstream from the dam, on the opposite side of a horseshoe bend. Water would be conveyed from the dam to the power plant through a tunnel and penstock, with a total length of 15,200 feet. The penstock, which would traverse the relatively level river bottom lands, would be buried and vegetation would be allowed to cover its location in order that as little as possible of the natural appearance of the Dinosaur National Monument in the vicinity of the dinosaur beds and the monument headquarters would be disturbed.

The generating equipment of Split Mountain Power Plant would consist of two 50,000-kilowatt units, making a total installed capacity of 100,000 kilowatts. The plant would operate under a mean head of about 300 feet. Sixty feet of this head would be gained in the river gradient between the dam and the power plant. The initial power generation with all the project units in coordinated operation would amount to about 710,000,000 kilowatt-hours annually. With ultimate stream flow conditions, the power generation would amount to about 441,000,000 kilowatt-hours

annually. Tailwater elevation at the power plant would be about 4,735 feet.

Necessary facilities would be constructed to distribute the electric energy to the various load centers and points of interconnection.

Access

A secondary road now extends 10 miles from Jensen, Utah, on United States Highway No. 40, to a point about a mile downstream from Split Mountain Dam site. The distance from the end of the road to the dam site must now be traveled by foot. An access highway could be constructed along the existing road. By use of a bridge this road could be extended across the river and then continued up the north side of the river to the dam. A connecting highway between the Split Mountain unit and the Echo Park unit may be found desirable.

Rights-of-Way and Relocation

There are no facilities within the reservoir area that would require relocation. The reservoir would inundate the center area of Island Park, part of which is privately owned.

Geology

Split Mountain Dam would rest on a foundation of Madison limestone. This rock has some undesirable characteristics but it is considered adequate to support a concrete, gravity-type dam. There is one fault in the vicinity of the dam site, with the strike extending in a north-south direction. The displacement is nearly zero at the point where the fault intersects the dam axis.

Drilling explorations in the vicinity of the site indicate the river fill material is about 30 feet deep at the dam axis.

Extensive gravel deposits are found downstream from the mouth of the canyon on widespread terraces. These deposits are composed of well assorted gravels, some cobbles, and considerable sand. Ample quantities of acceptable aggregate for construction of the dam are available within a 3- or 4-mile haul.

Cost Estimates

Estimated costs of the Split Mountain unit, based on December 1949 prices, are summarized in the table on the following page.

ESTIMATED COSTS OF SPLIT MOUNTAIN UNIT

Feature	Construction costs	Annual costs		
		Operation and maintenance costs	Replacement costs	Total
Dam and reservoir	$32,700,000	$ 6,600	$ 6,700	$ 13,300
Access road	1,700,000			
Rights-of-way	100,000			
Construction camp	700,000			
Power plant	10,900,000	171,800	132,300	304,100
Power tunnel	16,800,000			
Transmission facilities	13,500,000	189,000	152,600	341,600
Total	$76,400,000	$367,400	$291,600	$659,000

upper

Whitewater Unit

Now Dominguez with w.s. @4800

Dam and Reservoir

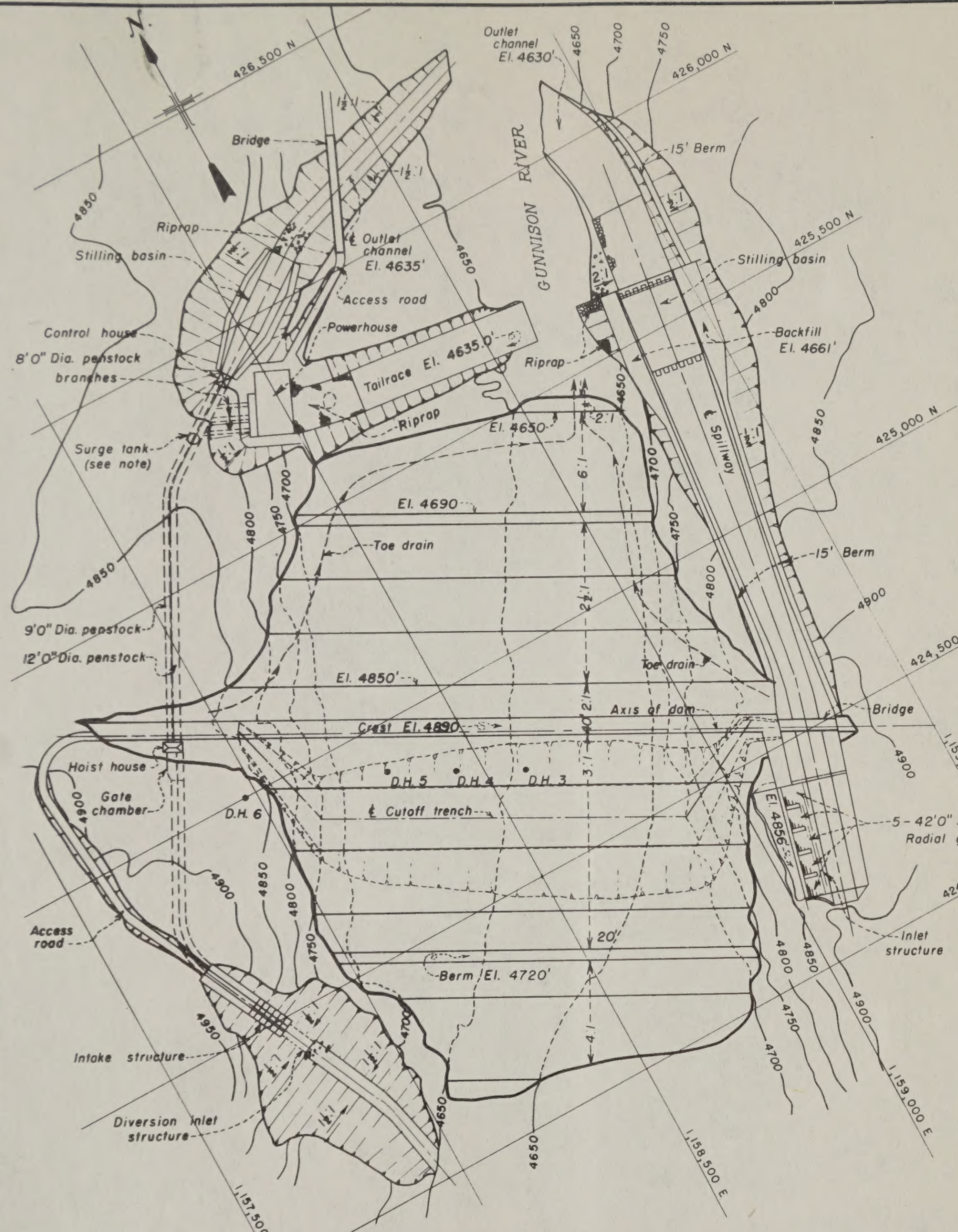
Whitewater Dam, key feature of the Whitewater unit, would be located in Mesa County, western Colorado. It would be on the Gunnison River, 2 miles south of Whitewater, Colo., and 9½ miles southeast of Grand Junction, Colo. The dam would be located 15 river miles upstream from the confluence of the Gunnison and Colorado Rivers.

Preliminary designs for the Whitewater Dam are shown on the drawings on the following pages.

The dam would be a rolled, earth-fill embankment with a volume of 6,656,000 cubic yards. It would rise 255 feet above stream bed and 335 feet above bedrock. The crest would be at elevation 4,890 feet, 10 feet above the normal water surface elevation. The crest would be 1,830 feet in length. To complete the reservoir basin three dikes would be constructed in low saddles on the north side of Kannah Creek about 4 miles upstream from the dam.

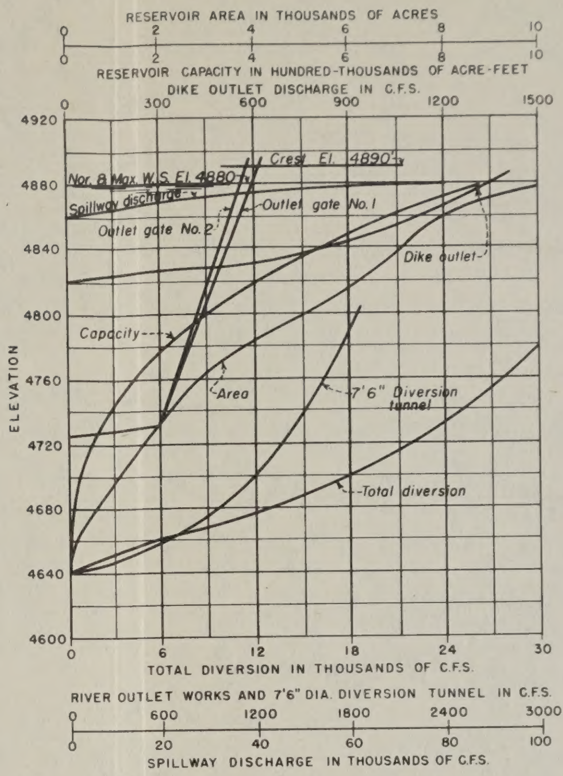
298,000

The reservoir formed by the dam and dikes would have a total initial capacity of 880,000 acre-feet, including an active capacity of 470,000 acre-feet and an inactive capacity of 410,000 acre-feet. In 200 years silt deposits would reduce the active capacity to 326,000 acre-feet and the inactive capacity to 92,000 acre-feet. When filled to capacity, the reservoir would have a water surface area of 10,250 acres and would extend about 35 river miles upstream to a point about 4 miles west of Delta, Colo.

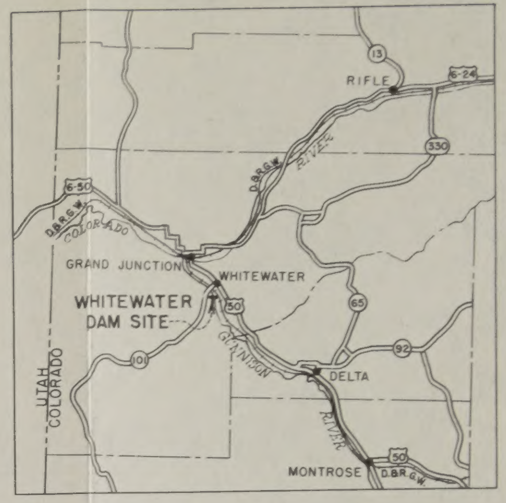

N.
426,500 N
426,000 N
425,500 N
425,000 N
424,500 N
424,000 N
Outlet channel El. 4630'
4650
4700
4750
15' Berm
Bridge
1½:1
Riprap
Stilling basin
Outlet channel El. 4635'
GUNNISON RIVER
Access road
Powerhouse
Control house
8'0" Dia. penstock branches
Tailrace El. 4635.0'
Riprap
Stilling basin
Backfill El. 4661'
4800
Surge tank (see note)
El. 4650
2:1
6:1
Spillway
4850
El. 4690
Toe drain
15' Berm
4900
9'0" Dia. penstock
12'0" Dia. penstock
El. 4850'
2½:1
Toe drain
Axis of dam
Bridge
Crest El. 4890
3:1
Hoist house
D.H.5
D.H.4
D.H.3
D.H.6
Gate chamber
Cutoff trench
El. 4856
5 - 42'0" x 20'0" Radial gates
1,159,500 E
Access road
20'
Berm El. 4720'
Inlet structure
Intake structure
4:1
Diversion inlet structure
1,159,000 E
1,158,500 E
1,157,500 E

GENERAL PLAN

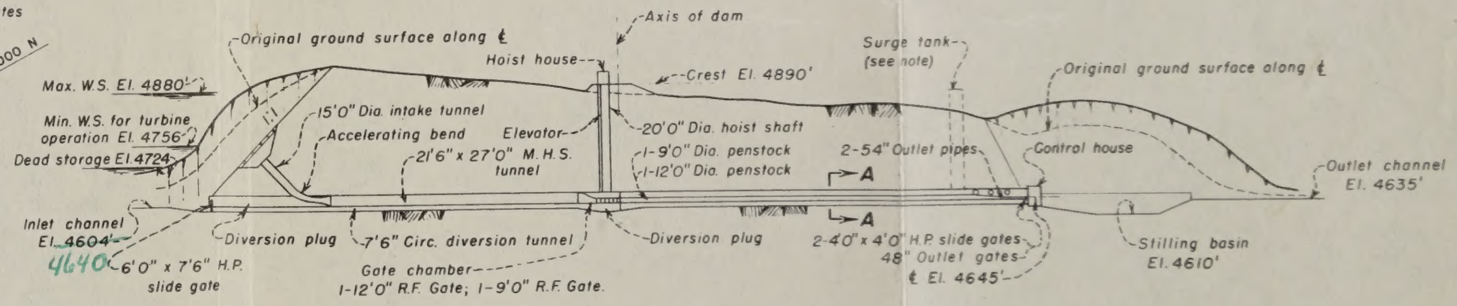
200 0 200 400
SCALE OF FEET



AREA-CAPACITY-DISCHARGE CURVES


13
RIFLE
6-24
330
6-50
D.&R.G.W.
COLORADO
GRAND JUNCTION
WHITEWATER
WHITEWATER DAM SITE
50
65
UTAH
COLORADO
GUNNISON
RIVER
141
DELTA
92
MONTROSE
50
D.&R.G.W.

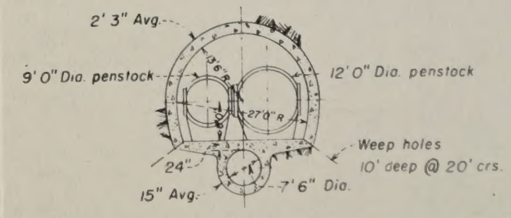
LOCATION MAP


Axis of dam
Original ground surface along ℄
Hoist house
Crest El. 4890'
Surge tank (see note)
Original ground surface along ℄
Max. W.S. El. 4880'
15'0" Dia. intake tunnel
Elevator
20'0" Dia. hoist shaft
Min. W.S. for turbine operation El. 4756'
Accelerating bend
1-9'0" Dia. penstock
1-12'0" Dia. penstock
2-54" Outlet pipes
Control house
Dead storage El. 4724
21'6" x 27'0" M.H.S. tunnel
A
Outlet channel El. 4635'
Inlet channel El. 4604'
4640
6'0" x 7'6" H.P. slide gate
Diversion plug
7'6" Circ. diversion tunnel
Diversion plug
A
2-4'0" x 4'0" H.P. slide gates
48" Outlet gates
℄ El. 4645'
Stilling basin El. 4610'
Gate chamber
1-12'0" R.F. Gate; 1-9'0" R.F. Gate.

PROFILE ON ℄ OF OUTLET WORKS

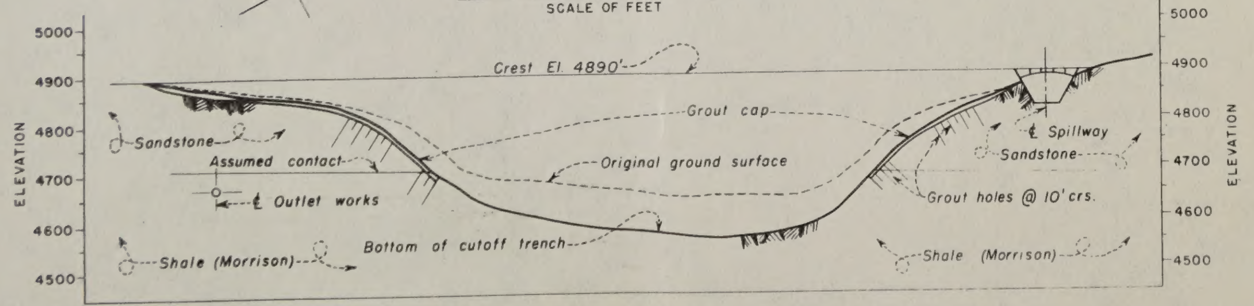
NOTE: A surge tank may or may not be required for the River outlet works depending on further detailed studies.

Material on this drawing traced from Denver office drawing 588-D-1.


2' 3" Avg.
9'0" Dia. penstock
12'0" Dia. penstock
27'0" R
Weep holes 10' deep @ 20' crs.
24"
15" Avg.
7'6" Dia.

SECTION A-A

10 0 10 20 30
SCALE OF FEET


5000
4900
4800
4700
4600
4500
ELEVATION
Crest El. 4890'
Grout cap
Sandstone
Assumed contact
Original ground surface
℄ Spillway
Sandstone
℄ Outlet works
Grout holes @ 10' crs.
Bottom of cutoff trench
Shale (Morrison)
Shale (Morrison)
5000
4900
4800
4700
4600
4500
ELEVATION

PROFILE ON ℄ OF CUTOFF TRENCH

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WHITEWATER UNIT-COLORADO RIVER STORAGE PROJECT

WHITEWATER DAM AND DIKES

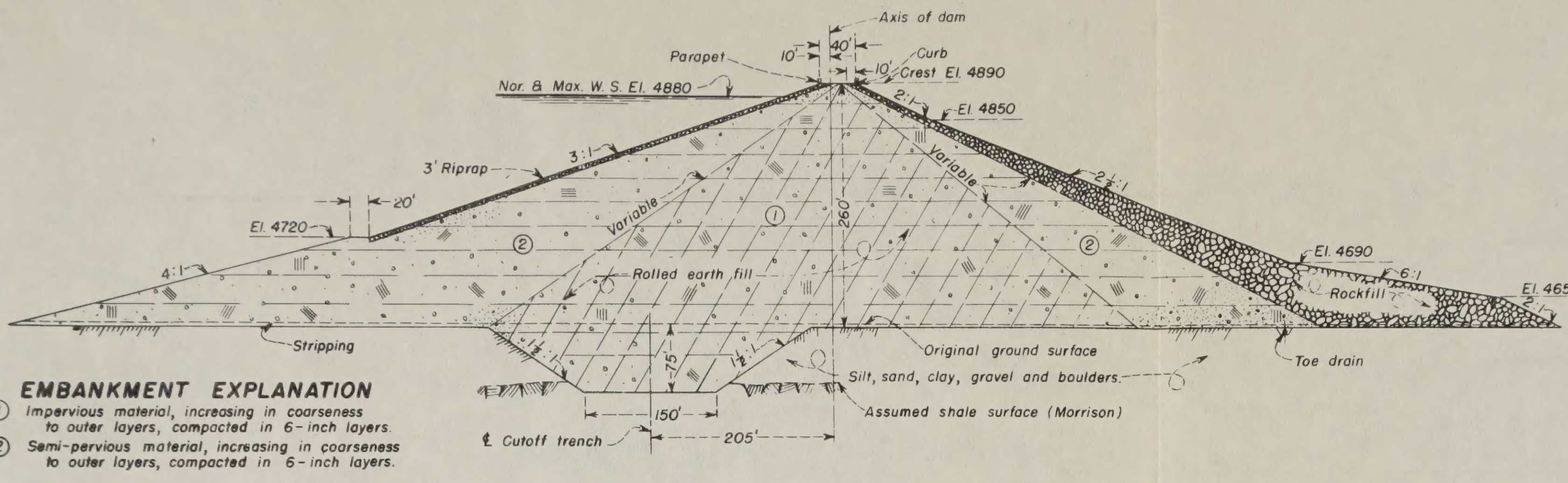
GENERAL PLAN AND SECTIONS
PRELIMINARY ESTIMATE DRAWING

DRAWN	H.W.C.	SUBMITTED	F.C.W. C. G. Jacobson
TRACED	R.B.R.	RECOMMENDED	K.B. Keener
CHECKED	E.C.P. E.P.C.	APPROVED	O.L. Rice ACT. CHIEF DESIGNING ENGINEER

NOV. 11-10-50 E.C.B.

SALT LAKE CITY, UTAH JULY 28, 1950
SHEET ONE OF TWO

588-414-5


Axis of dam
Parapet
10'
40'
Curb
10'
Crest El. 4890
Nor. & Max. W. S. El. 4880
2:1
El. 4850
3:1
3' Riprap
Variable
2½:1
20'
El. 4720
Variable
①
260'
②
②
El. 4690
4:1
Rolled earth fill
6:1
Rockfill
El. 4650
2:1
Stripping
Original ground surface
Toe drain
1½:1
75'
1½:1
Silt, sand, clay, gravel and boulders
150'
Assumed shale surface (Morrison)
℄ Cutoff trench
205'

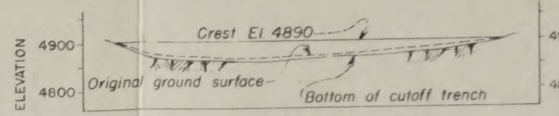
EMBANKMENT EXPLANATION

① Impervious material, increasing in coarseness to outer layers, compacted in 6-inch layers.

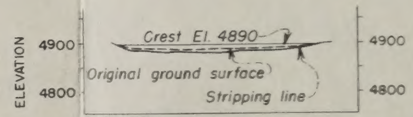
② Semi-pervious material, increasing in coarseness to outer layers, compacted in 6-inch layers.

MAXIMUM SECTION OF DAM

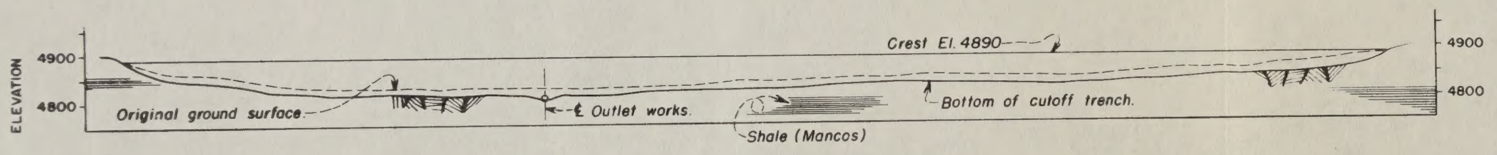
100 0 100 200
SCALE IN FEET


ELEVATION
4900
4800
Crest El. 4890
Original ground surface
Bottom of cutoff trench
4900
4800

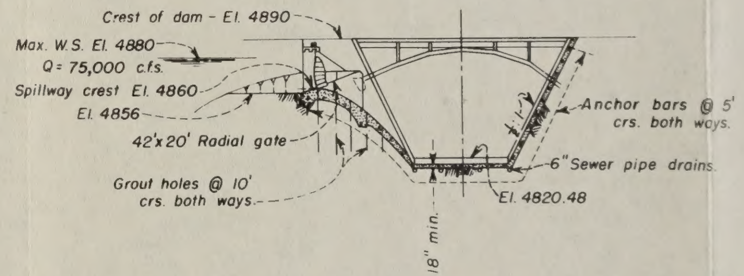
PROFILE ON ℄ OF CUTOFF TRENCH DIKE 2-C


ELEVATION
4900
4800
Crest El. 4890
Original ground surface
Stripping line
4900
4800

PROFILE ON AXIS OF DIKE 2-B

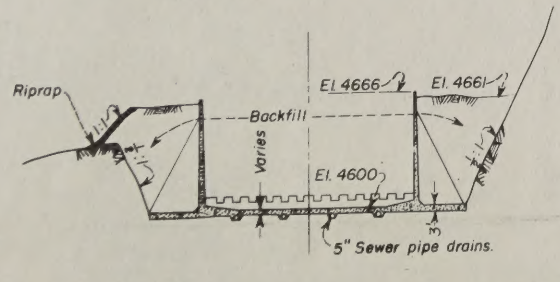

ELEVATION
4900
4800
Crest El. 4890
Original ground surface
℄ Outlet works.
Bottom of cutoff trench.
Shale (Mancos)
4900
4800

PROFILE ON ℄ OF CUTOFF TRENCH OF DIKE 2-A

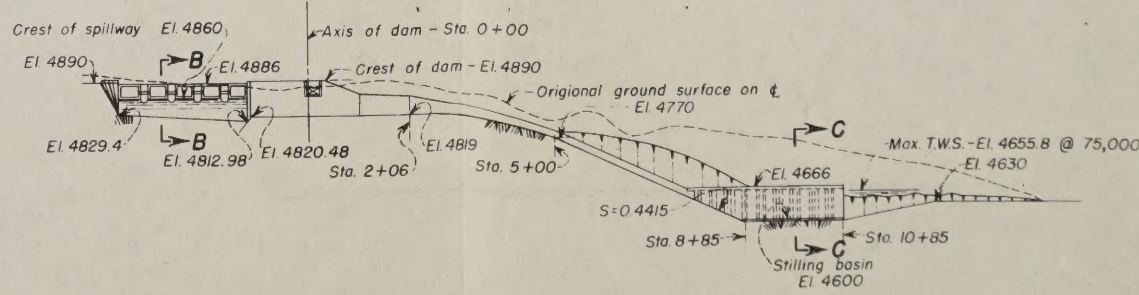

Crest of dam - El. 4890
Max. W.S. El. 4880
Q = 75,000 c.f.s.
Spillway crest El. 4860
El. 4856
42'x20' Radial gate
Anchor bars @ 5' crs. both ways.
1½:1
6" Sewer pipe drains.
Grout holes @ 10' crs. both ways.
El. 4820.48
18" min.

SECTION B-B

NOTE: Material on this drawing traced from Denver office drawing 588-D-1.


Riprap
El. 4666
El. 4661
Backfill
Varies
El. 4600
1½:1
5" Sewer pipe drains.
3'

SECTION C-C


Crest of spillway El. 4860
Axis of dam - Sta. 0+00
El. 4890
B
El. 4886
Crest of dam - El. 4890
Origional ground surface on ℄
El. 4770
El. 4829.4
B
El. 4812.98
El. 4820.48
Sta. 2+06
El. 4819
Sta. 5+00
C
Max. T.W.S. - El. 4655.8 @ 75,000 c.f.s.
El. 4630
El. 4666
S = 0.4415
Sta. 8+85
C
Sta. 10+85
Stilling basin El. 4600

PROFILE ALONG ℄ SPILLWAY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

WHITEWATER UNIT-COLORADO RIVER STORAGE PROJECT

WHITEWATER DAM AND DIKES

GENERAL PLAN AND SECTIONS
PRELIMINARY ESTIMATE DRAWING

NOV. 10-50 E.C.B.

DRAWN H.W.C. SUBMITTED F.C.W. E. B. Jacobson
TRACED J.K.A. RECOMMENDED K.B. Keener
CHECKED E.C.P. E.P.C. APPROVED O.L. Rice
ACT. CHIEF DESIGNING ENGINEER

SALT LAKE CITY, UTAH JULY 28, 1950
SHEET TWO OF TWO

588-414-6

Diversion, spillway, and outlet works. During construction of Whitewater Dam the river flow would be diverted through two permanent outlet tunnels in the left abutment. These tunnels would discharge a maximum of 22,700 second-feet.

A side-channel, chute-type spillway would be located on the right abutment of the dam. It would discharge a maximum of 75,000 second-feet over a crest elevation of 4,860 feet.

River outlet works would be provided in the left abutment in conjunction with the outlets of the Whitewater power plant. These would discharge 1,~~2~~500 second-feet with the water surface at elevation ~~4,730~~ 4,756 feet.

An outlet with a capacity of 800 second-feet would be installed in one of the dikes (dike 2A) to deliver water to the potential Kannah Creek Irrigation Canal.

Power Features

Whitewater Power Plant would be located at the toe of the dam and would consist of three equal-sized units with a total installed capacity of 48,000 kilowatts. The plant would operate under a maximum head of 240 feet and a mean head of about 220 feet. The initial energy generation of the plant with all project units in coordinated operation would amount to 249,000,000 kilowatt-hours annually. With ultimate stream flow depletions, approximately 187,000,000 kilowatt-hours could be produced annually. The power penstocks would be placed in the outlet tunnel. Tailwater elevation at the power plant would be about 4,640 feet.

Transmission facilities would be provided as necessary to distribute the electric energy produced to various load centers and points of interconnection.

Access

The dam site is readily accessible since it is located only 1 mile from United States Highway No. 50 and is situated directly on a branch line of the Denver and Rio Grande Western Railroad. At the present time both abutments can be reached by dirt roads.

Rights-of Way and Relocation

A small part of the reservoir area consists of improved farm lands. It contains no centers of population. About 28 miles of the Denver and Rio Grande Western Railroad would require relocation. Other facilities requiring relocation within the reservoir area are United States Highway No. 50, some secondary roads, a Mountain States Telephone and Telegraph Company line, and a Western Union telegraph line.

Geology

At the dam site the Gunnison River has cut through Mancos shale and Dakota sandstone and has exposed the upper part of the Morrison formation. This Morrison formation would form the foundation for the dam. It is generally soft and easily weathered. The Dakota sandstone, which would form the abutments for the dam, is predominantly hard and resistant. Six holes, drilled to investigate the foundation, showed the maximum depth of overburden to be 68.5 feet. Percolation tests showed no abnormal seepage losses. The three dikes would have adequate foundation support and tight abutments.

Four borrow areas have been explored as possible sources of construction materials. Tests made on the samples taken show the materials to be ample and acceptable for the fill. Concrete aggregate and riprap are also available.

Cost Estimates

Estimated costs of the Whitewater unit, based on December 1949 prices, are summarized in the following table.

ESTIMATED COSTS OF WHITEWATER UNIT

		Annual costs		
Feature	Construction costs	Operation and maintenance costs	Replacement costs	Total
Dam and reservoir	$18,400,000	11,000	$ 3,800	$ 14,800
Access facilities	100,000			
Rights-of-way and relocation	5,100,000			
Construction camp	400,000			
Power plant	9,500,000	105,600	68,500	174,100
Transmission system	6,500,000	90,700	73,200	163,900
Total	$40,000,000	$207,300	$145,500	$352,800

Summary

Design Data

Information on the units included in the storage project is summarized in the table on the following page.

SUMMARIZED DATA ON UNITS OF COLORADO RIVER STORAGE PROJECT

Unit	River	Height of dam above river (feet)	Active storage capacity (acre-feet)		Inactive storage capacity (acre-feet)		Power installation (kilowatts)
			Initial	After 200 years of sediment encroachment	Initial	After 200 years of sediment encroachment	
Cross Mountain	Yampa	295 ✓	4,200,000	4,030,000	1,000,000	887,000	60,000 -6
Crystal	Gunnison	305 ✓	0	0	40,000	40,000	48,000 -8
Curecanti	Gunnison	475 ✓	2,010,000	1,979,000	490,000	463,000	54,000 -7
Echo Park	Green	525 ✓	5,460,000	5,169,000	1,000,000	753,000	200,000 -3
Flaming Gorge	Green	440 ✓	2,950,000	2,550,000	990,000	11,000	72,000 -5
Glen Canyon	Colorado	580 ✓	20,000,000	10,455,000	6,000,000	0	800,000 -1
Gray Canyon	Green	445 ✓	1,390,000	698,000	610,000	0	210,000 -2
Navajo	San Juan	335 ✓	1,050,000	734,000	150,000	33,000	30,000 -9
Split Mountain	Green	245 ✓	0	0	335,000	335,000	100,000 -4
Whitewater	Gunnison	255 ✓	470,000	326,000	410,000	92,000	48,000 8
Total			37,530,000	25,941,000	11,025,000	2,614,000	1,622,000

Cost Estimates

Total construction costs and total annual costs, including operation, maintenance, and replacement costs, of the various project units are summarized in the following table. Estimated construction costs of the individual project features and detailed engineering data on the features are given on the following pages. The estimates given are based on December 1949 prices.

TOTAL PROJECT COSTS

Unit	Construction costs	Annual costs	
Cross Mountain	$ 51,000,000	$ 414,700	.813%
Crystal	37,900,000	325,500	.859
Curecanti	80,400,000	378,100	.470
Echo Park	165,400,000	1,199,200	.725
Flaming Gorge	82,700,000	483,900	.589
Glen Canyon	363,900,000	4,428,600	1.217
Gray Canyon	178,400,000	1,239,300	.695
Navajo	63,000,000	251,000	.398
Split Mountain	76,400,000	659,000	.863
Whitewater	40,000,000	352,800	.882
Total	$1,139,100,000 1/	$9,732,100	

1/ Does not include nonreimbursable money expended from Colorado River Development Fund for investigations and surveys nor costs of features in the programs recommended by cooperating agencies.

CROSS MOUNTAIN UNIT

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN MANUAL VOL. XXIII CH. 2.1 "PROJECT COST ESTIMATES"

COLORADO RIVER STORAGE PROJECT

REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS		MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ Facilities	~~INVESTIGATIONS & ENGINEERING~~	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
				BY CONTRACTOR	BY GOVERNMENT					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	CROSS MOUNTAIN UNIT									
01.	RESERVOIRS & DAMS									
01.01	CROSS MOUNTAIN DAM & RESERVOIR		1,000,000	20,384,000		4,436,000	100,000		4,984,000	$ 30,904,000
	Location - On Yampa River 58½ Mi. above mouth.									
	Res. Storage 5,200,000 AF									
	Nor. & Max. W.S. El. 6,090 Ft									
	Type of dam - Conc. Gravity									
	Vol. of dam 431,000 cy									
	Crest elev. 6,095 Ft									
	Crest width 40 Ft									
	Crest length 550 Ft									
	Ht. of dam above stream 295 Ft									
	Ht. of dam above found. 355 Ft									
	Present River El. 5,800 Ft									
	Spillway Capy. 45,000 sf									
	Outlet Capy. 5,000 sf									
	Diversion Capy. 10,000 sf									
	Excav., rock, for dam 80,000 cy									
	Excav., common, for dam 97,000 cy									
11.	POWER PLANTS - HYDRO.									
11.01	CROSS MOUNTAIN POWER PLANT			4,344,000	—	5,259,000	50,000	—	1,834,000	11,487,000
	Installed Capy. - 60,000 Kw Mean oper. head 400 Ft									
	No. of Units 2 Max. static head 440 Ft									
	Tailwater Elev. - 5,650 Ft Tunnel len. & dia. 11,700 Ft - 17.5 Ft									
13.	TRANSMISSION SYSTEM		81,000	1,944,000		4,754,000	25,000		1,296,000	8,100,000
	Transmissions lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			167,000		225,000	25,000		83,000	500,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(200,000)			(200,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$ 50,991,000
									Rounded	$ 51,000,000

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

COLORADO RIVER STORAGE PROJECT

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN MANUAL VOL. XXIII CH. 2.1 "PROJECT COST ESTIMATES"

REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS		MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ FACILITIES	~~INVESTIGATIONS & ENGINEERING~~	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
				BY CONTRACTOR	BY GOVERNMENT					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	CRYSTAL UNIT									
01.	RESERVOIRS & DAMS									
01.01	CRYSTAL DAM & RESERVOIR			16,426,000		4,748,000	100,000		4,255,000	$25,529,000
	Location - 14 mi. East of Montrose on Gunn. River									
	Res. Storage 40,000 AF									
	Nor. & Max. W.S. El. 6,870 Ft									
	Type of Dam - Conc., gravity									
	Vol. of dam 494,000 cy									
	Crest Elev. 6,875 Ft									
	Crest width 40 Ft									
	Crest length 620 Ft									
	Ht. of dam above stream 305 Ft									
	Ht. of dam above found. 355 Ft									
	Present Riv. El. 6,570 Ft									
	Spillway Capy. 48,000 sf									
	Outlet Capy. 2,000 sf									
	Diversion Capy. 22,500 sf									
	Excav., rock, for dam 107,400 cy									
	Excav., common, for dam 19,700 cy									
11.	POWER PLANTS - HYDRO									
11.01	CRYSTAL POWER PLANT			2,093,000		2,533,000	25,000		884,000	5,535,000
	Installed Capy. - 48,000 Kw Mean Oper. Head. - 300 Ft									
	No. of Units - 3 Max. Static Head. - 300 Ft									
	Tailwater Elev. - 6,570 Ft									
13.	TRANSMISSION SYSTEM		65,000	1,555,000		3,798,000	25,000		1,037,000	6,480,000
	Transmission lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			120,000		155,000	25,000		60,000	360,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(175,000)			(175,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$37,904,000
									Rounded	$37,900,000

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

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COLORADO RIVER STORAGE PROJECT

REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS		MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ FACILITIES	~~INVESTIGATIONS & ENGINEERING~~	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
				BY CONTRACTOR	BY GOVERNMENT					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	CURECANTI UNIT									
01.	RESERVOIRS & DAMS									
01.01	BLUE MESA DAM & CURECANTI RES.		680,000	43,987,000		11,746,000	200,000		10,068,000	$66,681,000
	Location – 3½ mi. west of Sapinero-Gunn. River									
	Res. Storage 2,500,000 AF									
	Nor. & Max. W.S. El. 7,635 Ft									
	Type of Dam – Conc. Grav.									
	Vol. of Dam 1,745,000 cy									
	Crest elev. 7,640 Ft									
	Crest width 40 Ft									
	Crest length 1,240 Ft									
	Ht. of dam above stream 475 Ft									
	Ht. of dam above found. 510 Ft									
	Present River elev. 7,165 Ft									
	Spillway Capy. 48,000 sf									
	Outlet Capy. 2,000 sf									
	Diversion Capy. 22,500 sf									
	Excav., rock, for dam 221,700 cy									
	Excav., common, for dam 19,000 cy									
11.	POWER PLANTS – HYDRO									
11.01	BLUE MESA POWER PLANT			2,105,000		2,548,000	25,000		842,000	5,520,000
	Installed Capy. – 54,000 Kw Mean Oper. Head. – 425 Ft									
	No. of Units – 3 Max. Static Head. – 470 Ft									
	Tailwater Elev. – 7,165 Ft									
13.	TRANSMISSION SYSTEM		73,000	1,750,000		4,276,000	25,000		1,166,000	7,290,000
	Transmission lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			305,000		408,000	50,000		137,000	900,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(300,000)			(300,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$80,391,000
									Rounded	$80,400,000

ECHO PARK UNIT

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

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COLORADO RIVER STORAGE PROJECT

REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS		MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ Facilities	~~INVESTIGATIONS & ENGINEERING~~	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
				BY CONTRACTOR	BY GOVERNMENT					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	ECHO PARK UNIT									
01.	RESERVOIRS & DAMS									
01.01	ECHO PARK DAM & RESERVOIR (includes access road)		175,000	78,503,000		21,668,000	400,000		16,091,000	$116,837,000
	Location - On Green River, 28 Mi. East of Vernal.									
	Res. Storage 6,460,000 AF									
	Nor. & Max. W.S. El. 5,570 Ft									
	Type of dam - Conc. Curved Gravity									
	Vol. of dam 2,680,000 cy									
	Crest elev. 5,575 Ft									
	Crest width 30 Ft									
	Crest length 920 Ft									
	Ht. of dam above stream 525 Ft									
	Ht. of dam above found. 690 Ft									
	Present River Elev. 5,050 Ft									
	Spillway Capy. 81,500 sf									
	Outlet Capy. 20,000 sf									
	Diversion Capy. 27,500 sf									
	Excav., rock, for dam 750,000 cy									
	Excav., common, for dam 1,110,000 cy									
11.	POWER PLANTS - HYDRO									
11.01	ECHO PARK POWER PLANT			7,669,000		9,274,000	100,000		2,726,000	19,769,000
	Installed Capy. - 200,000 Kw Mean oper. head 475 Ft									
	No. of Units 4 Max. static head 520 Ft									
	Tailwater elev. 5,050 Ft									
13.	TRANSMISSION SYSTEM		270,000	6,480,000		15,830,000	100,000		4,320,000	27,000,000
	Transmissions lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			604,000		805,000	100,000		241,000	1,750,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(700,000)			(700,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$165,356,000
									Rounded	$165,400,000

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

INSTRUCTIONS FOR USE OF THIS
FORM ARE CONTAINED IN MANUAL
VOL. XXIII CH. 2.1 "PROJECT COST ESTIMATES"

COLORADO RIVER STORAGE PROJECT

REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS		MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ FACILITIES	~~INVESTIGATIONS & ENGINEERING~~	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
				BY CONTRACTOR	BY GOVERNMENT					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	FLAMING GORGE UNIT									
01.	RESERVOIRS & DAMS									
01.01	ASHLEY DAM & FLAMING GORGE RESERVOIR		200,000	42,628,000		11,525,000	200,000		9,784,000	$64,337,000
	Location - On Green River, 32 mi. north of Vernal. (airline miles)									
	Res. Storage 3,940,000 AF									
	Nor. & Max. W.S. El. 6,040 Ft									
	Type of dam - Conc. gravity									
	Volume of dam 1,725,000 cy									
	Crest elev. 6,045 Ft									
	Crest width 40 Ft									
	Crest length 900 Ft									
	Ht. of dam above stream 440 Ft									
	Ht. of dam above found. 491 Ft									
	Present Riv. Elev. 5,605 Ft									
	Spillway Capy. 85,000 sf									
	Outlet Capy. 5,000 sf									
	Diversion Capy. 20,000 sf									
	Excav., rock, for dam 291,000 cy									
	Excav., common, for dam 77,100 cy									
11.	POWER PLANTS - HYDRO									
11.01	ASHLEY POWER PLANT			2,940,000		3,569,000	25,000		1,176,000	7,710,000
	Installed Capy. - 72,000 Kw Mean Oper. head - 395 Ft									
	No. of Units 3 Max. Static head - 435 Ft									
	Tailwater elev. - 5,605 Ft									
13.	TRANSMISSION SYSTEM		97,000	2,333,000		5,710,000	25,000		1,555,000	9,720,000
	Transmission lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			305,000		458,000			137,000	900,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(255,000)			(255,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$82,667,000
									Rounded	$82,700,000

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

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COLORADO RIVER STORAGE PROJECT

REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS BY CONTRACTOR	LABOR & MATERIALS BY GOVERNMENT	MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ FACILITIES	~~INVESTIGATIONS & ENGINEERING~~	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	GLEN CANYON UNIT									
01.	RESERVOIRS & DAMS									
01.01	GLEN CANYON DAM & RESERVOIR		401,000	120,552,000		30,120,000	600,000		24,204,000	$175,877,000
	Location - On Colo. Riv., 15 mi. upstream from Lees Ferry									
	Res. Storage 26,000,000 AF									
	Normal W.S. El. 3,700 Ft									
	Max. W.S. El. 3,710 Ft									
	Type of Dam - Conc., curved, gravity									
	Vol. of Dam 5,060,000 cy									
	Crest Elev. 3,715 Ft									
	Crest Width 45 Ft									
	Crest Length 1,400 Ft									
	Present Riv. El. 3,135 Ft									
	Ht. of dam above stream 580 Ft									
	Ht. of dam above found. 700 Ft									
	Spillway Capy. 253,000 sf									
	Outlet Capy. 20,000 sf									
	Diversion Capy. 120,000 sf									
	Excav., rock for dam 1,900,000 cy									
	Excav., common for dam 612,000 cy									
11.	POWER PLANTS - HYDRO									
11.01	GLEN CANYON POWER PLANT			31,366,000		33,680,000	300,000		10,455,000	75,801,000
	Installed Capacity - 800,000 Kw Mean Oper. Head. - 480 Ft									
	No. of Units - 7 Max. Static Head - 560 Ft									
	Tailwater Elev. - 3,140 Ft									
13.	TRANSMISSION SYSTEM		1,080,000	25,920,000		63,420,000	300,000		17,280,000	108,000,000
	Transmission lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			1,466,000		1,998,000	200,000		586,000	4,250,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(1,400,000)			(1,400,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$363,928,000
									Rounded	$363,900,000

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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COLORADO RIVER STORAGE PROJECT

REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE (1)	PROPERTY AND DESCRIPTION (2)	PREVIOUS OFFICIAL ESTIMATE (3)	DETAIL OF CURRENT ESTIMATE OF PROJECT COST: LAND & LAND RIGHTS (4)	LABOR & MATERIALS: BY CONTRACTOR (5)	LABOR & MATERIALS: BY GOVERNMENT (6)	MATERIALS & EQUIPMENT PERMANENTLY INSTALLED (7)	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ FACILITIES (8)	~~INVESTIGATIONS & ENGINEERING~~ (9)	~~ADMINISTRATIVE &~~ GENERAL EXPENSES (10)	CURRENT OFFICIAL ESTIMATE (11)
	GRAY CANYON UNIT									
01.	RESERVOIRS & DAMS									
01.01	GRAY CANYON DAM & RES.		50,000	84,228,000		25,667,000	500,000		17,663,000	$128,108,000
	Location - On Green River 22 Mi. upstream from Green River U.									
	Res. Storage 2,000,000 AF									
	Nor. & Max. W.S. El. 4,590 Ft									
	Type of dam - Conc. Gravity									
	Vol. of dam 3,595,000 cy									
	Crest elev. 4,595 Ft									
	Crest width 40 Ft									
	Crest length 2,100 Ft									
	Ht. of dam above stream 445 Ft									
	Ht. of dam above found. 575 Ft									
	Present River El. 4,150 Ft									
	Spillway Capy. 190,000 sf									
	Outlet Capy. 10,000 sf									
	Diversion Capy. 100,000 sf									
	Excav., rock, for dam 682,000 cy									
	Excav., common, for dam 654,000 cy									
11.	POWER PLANTS - HYDRO									
11.01	GRAY CANYON POWER PLANT			7,743,000	—	9,363,000	100,000		2,753,000	19,959,000
	Installed Capy. - 210,000 KW Mean. oper. head 400 Ft									
	No. of Units 4 Max. static head 440 Ft									
	Tailwater Elev. - 4,150 Ft.									
13.	TRANSMISSION SYSTEM		284,000	6,804,000		16,626,000	100,000		4,536,000	28,350,000
	Transmissions lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			690,000		934,000	100,000		276,000	2,000,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(800,000)			(800,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$178,417,000
									Rounded	$178,400,000

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

COLORADO RIVER STORAGE PROJECT

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REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS		MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ Facilities	~~INVESTIGATIONS & ENGINEERING~~	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
				BY CONTRACTOR	BY GOVERNMENT					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	NAVAJO UNIT									
01.	RESERVOIRS & DAMS									
01.01	NAVAJO DAM & RESERVOIR		500,000	33,930,000		9,852,000	200,000		7,917,000	$ 52,399,000
	Location - 19½ Mi. East of Blanco N.M. S.J.R.									
	Res. Storage 1,200,000 AF									
	Nor. & Max. W.S. El. 6,050 Ft									
	Type of dam - Earth Fill									
	Vol. of dam 17,000,000 cy									
	Crest elev. 6,060 Ft									
	Crest width 40 Ft									
	Crest length 3,280 Ft									
	Ht. of dam above stream 335 Ft									
	Ht. of dam above found. 360 Ft									
	Present River El. 5,725 Ft									
	Spillway Capy. 175,000 sf									
	Outlet Capy. 3,000 sf									
	Diversion Capy. 20,000 sf									
	Excav., rock, for dam 1,150 cy									
	Excav., common, for dam (600,000 cy)									
11.	POWER PLANT - HYDRO									
11.01	NAVAJO POWER PLANT			2,201,000		2,665,000	25,000		979,000	5,870,000
	Installed Capy. - 30,000 Kw Mean oper. head 275 Ft									
	No. of Units 3 Max. static head 325 Ft									
	Tailwater Elev. - 5,725 Ft									
13.	TRANSMISSION SYSTEM		40,000	972,000		2,380,000	10,000		648,000	4,050,000
	Transmissions lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			237,000		316,000	40,000		107,000	700,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(275,000)			(275,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$ 63,019,000
									Rounded	$ 63,000,000

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

COLORADO RIVER STORAGE PROJECT

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REGION 4
Date of Estimate Aug. 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS		MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ Facilities	~~INVESTIGATIONS & ENGINEERING~~	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
				BY CONTRACTOR	BY GOVERNMENT					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	SPLIT MOUNTAIN UNIT									
01.	RESERVOIRS & DAMS									
01.01	SPLIT MOUNTAIN DAM & RES.		50,000	22,276,000		6,437,000	150,000		5,484,000	$34,397,000
	Location - On Green River 14 Mi. East of Vernal									
	Res. Storage 335,000 AF									
	Nor. & Max. W.S. El. 5,050 Ft									
	Type of dam - Conc. Gravity									
	Vol. of dam 806,200 cy									
	Crest elev. 5,055 Ft									
	Crest width 40 Ft									
	Crest length 990 Ft									
	Ht. of dam above stream 245 Ft									
	Ht. of dam above found. 305 Ft									
	Present River elev. 4,810 Ft									
	Spillway Capy. 112,000 sf									
	Outlet Capy. 8,000 sf									
	Diversion Capy. 35,000 sf									
	Excav., rock, for dam 267,000 cy									
	Excav., common, for dam 185,000 cy									
11.	POWER PLANTS - HYDRO									
11.01	SPLIT MOUNTAIN POWER PLANT			10,659,000		12,877,000	150,000		4,026,000	27,712,000
	Installed Cap. - 100,000 Kw Mean oper. head 300 Ft									
	No. of Units 2 Max static head 304 Ft									
	Tailwater El. - 4,735 Ft Tunnel len. & dia. 11,700 Ft - 26 Ft									
13.	TRANSMISSION SYSTEM		135,000	3,240,000		7,915,000	50,000		2,160,000	13,500,000
	Transmissions lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			252,000		328,000	50,000		120,000	750,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(400,000)			(400,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$76,359,000
									Rounded	$76,400,000

WHITEWATER UNIT

Form: PF-1

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICIAL ESTIMATE OF TOTAL PROJECT COST

COLORADO RIVER STORAGE PROJECT

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN MANUAL VOL. XXIII CH. 2.1 "PROJECT COST ESTIMATES"

REGION 4
Date of Estimate August 14, 1950
Prices as of December 1949
SHEET 1 OF 1 SHEETS

CLASS & ACCOUNT REFERENCE	PROPERTY AND DESCRIPTION	PREVIOUS OFFICIAL ESTIMATE	DETAIL OF CURRENT ESTIMATE OF PROJECT COST							CURRENT OFFICIAL ESTIMATE
			LAND & LAND RIGHTS	LABOR & MATERIALS		MATERIALS & EQUIPMENT PERMANENTLY INSTALLED	~~TEMPORARY~~ CONSTRUCTION ~~PROPERTY~~ FACILITIES	INVESTIGATIONS & ENGINEERING	~~ADMINISTRATIVE &~~ GENERAL EXPENSES	
				BY CONTRACTOR	BY GOVERNMENT					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	WHITEWATER UNIT									
01.	RESERVOIRS & DAMS									
01.01	BRIDGEPORT DAM & WHITEWATER RESERVOIR (incl. 3 dikes)		500,000	15,608,000		3,582,000	100,000		3,838,000	$23,628,000
	Location - 9¼ mi. SE of Grand Junction on Gunn. River									
	Res. Storage 880,000 AF									
	Nor. & Max. W.S. El. 4,880 Ft									
	Type of Dam - Earth fill									
	Vol. of Dam 6,656,000 cy									
	Crest Elev. 4,890 Ft									
	Crest width 40 Ft									
	Crest length 1,830 Ft									
	Ht. of dam above stream 255 Ft									
	Ht. of dam above found. 335 Ft									
	Present Riv. Elev. 4,635 Ft									
	Spillway Capy. 75,000 sf									
	Outlet Capy. 1,500 sf									
	Diversion Capy. 22,700 sf									
	Excav., rock, for dam 33,000 cy									
	Excav., common, for dam 753,000 cy									
11.	POWER PLANTS - HYDRO									
11.01	BRIDGEPORT POWER PLANT			3,618,000		4,372,000	50,000		1,528,000	9,568,000
	Installed Capy. - 48,000 Kw Mean Oper. Head. - 220 Ft									
	No. of Units - 3 Max. Static Head - 240 Ft									
	Tailwater Elev. - 4,640 Ft									
13.	TRANSMISSION SYSTEM		65,000	1,555,000		3,803,000	20,000		1,037,000	6,480,000
	Transmission lines, switchyards, substations, etc.									
15.	GENERAL PROPERTY			133,000		180,000	20,000		67,000	400,000
	Town, utilities, and general service facilities.									
20.	CONSTRUCTION FACILITIES						(190,000)			(190,000)
	Temporary service structures, operating tools & equipment, operating plants, etc.									
	Total all classes									$40,076,000
									Rounded	$40,000,000

CONSTRUCTION SCHEDULE

The project units are scheduled for construction over an extended period. Each unit would be brought into operation as required to meet the needs for water-consuming uses and electric energy. In scheduling construction to make certain that project units would be in operation when needed, consideration was given to cyclic shifts in run-off conditions and to the advantages that would be gained by initially filling the reservoirs while unused apportioned water is available. The Whitewater, Echo Park, Glen Canyon, Navajo, and Flaming Gorge units are scheduled for initial construction.

Details of the construction schedule are shown by the bar diagram on the following page. The diagram also shows the years in which the generating units of the project power plants are expected to be in operation.

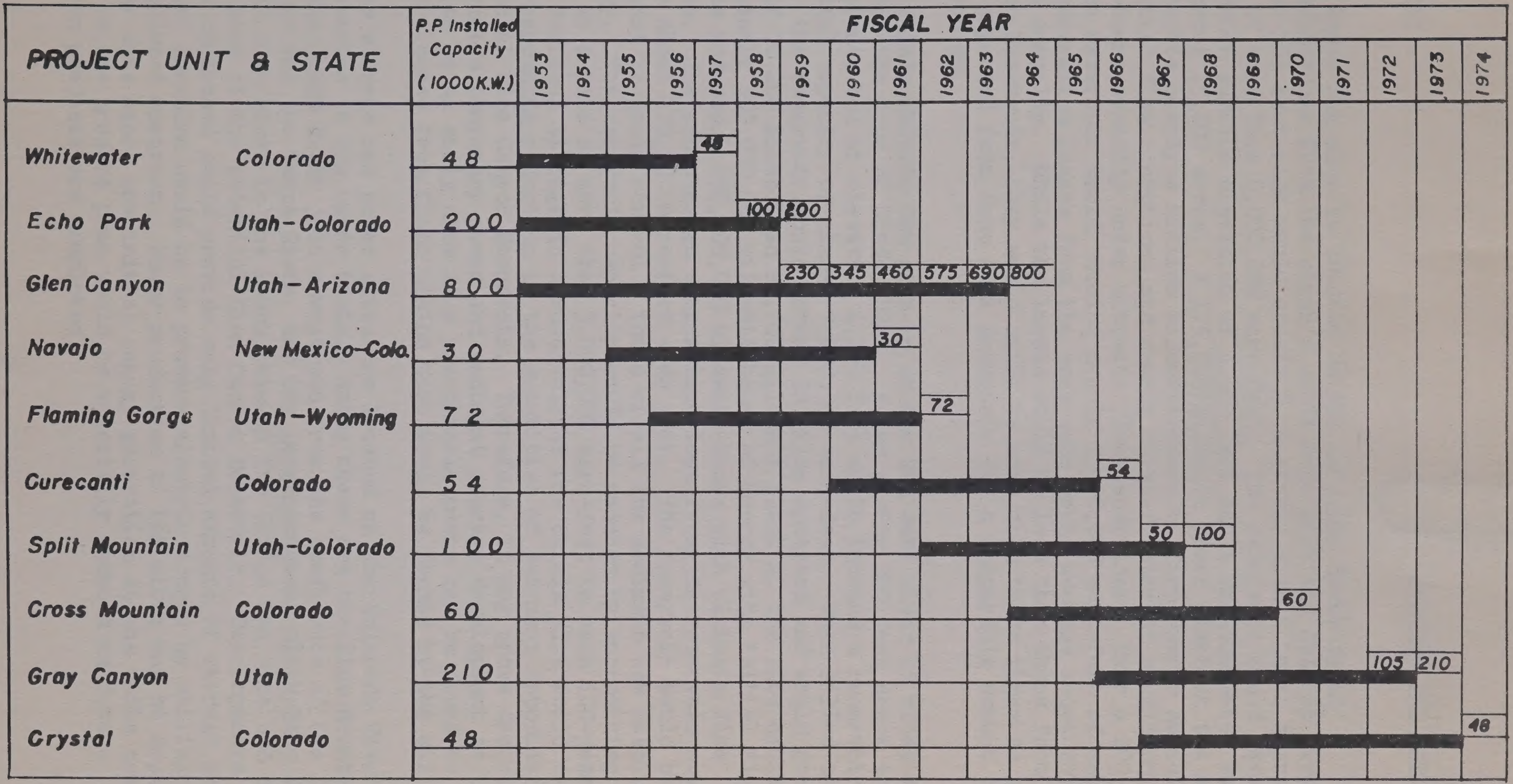
ALTERNATIVE FEATURES

Investigations to date indicate that the system of reservoirs included in the project plan would economically obtain the greatest possible water yield and power output with minimum loss of water from evaporation. Several alternative sites for power and storage development, including the Dewey on the Colorado River, the Desolation on the Green River, and the Chinle (Bluff) on the San Juan River, have been studied and excluded from the project plan because of certain physical disadvantages. Additional attention, however, should be given other storage and power developments in the near future to assure the maximum utilization of the basin's resources.

The Desolation Dam site is located on the Green River about 50 miles upstream from the town of Green River, Utah, and within the basin of the potential Gray Canyon Reservoir. A dam rising 385 feet above the present stream bed at elevation 4,400 feet would impound a reservoir with a total storage capacity of more than 8,000,000 acre-feet. The reservoir would have a maximum water surface area of 135,000 acres and a mean area of nearly 100,000 acres. Development of the reservoir would limit the Gray Canyon Dam to a height of 250 feet above stream bed and would limit the Gray Canyon Reservoir to a capacity of less than 500,000 acre-feet. The combination of Desolation Reservoir and a reduced Gray Canyon Reservoir, as compared to the Gray Canyon development included in the project plan, would increase active storage by about 5,000,000 acre-feet and would increase average firm energy generation by nearly 380,000,000 kilowatt-hours annually. The combination, however, would also result in average annual net evaporation losses of about 330,000 acre-feet annually, about four times the losses that would be realized at the Echo Park site for a comparable amount of active storage.

COLORADO RIVER STORAGE PROJECT

SCHEDULE OF CONSTRUCTION PROGRAM – FISCAL YEARS 1953-1974



48 Operating Power Plant Capacity (1000K.W.)

The Dewey Dam site is located on the Colorado River about 3 miles downstream from the river's confluence with the Dolores River. Here a dam 335 feet high would create a reservoir with a total storage capacity of more than 8,000,000 acre-feet. The reservoir would have a maximum water surface elevation of 4,410 feet and a maximum water surface area of about 75,000 acres. A 175,000-kilowatt power plant at the site could generate nearly a billion kilowatt-hours of firm energy annually under initial flow conditions and nearly three-fourths of a billion kilowatt-hours annually under ultimate flow conditions. Over a 200-year period the reservoir would receive nearly 2,500,000 acre-feet of sediment. Evaporation losses from the reservoir would average about 253,000 acre-feet annually. While the losses would be less than those from Desolation Reservoir, they would still be more than three times as great as those expected from Echo Park Reservoir for a comparable amount of active storage.

4196
360
4556

The Chinle (Bluff) Dam site is on the San Juan River 15 miles downstream from the town of Bluff, Utah. A dam rising 360 feet above the present stream bed at elevation 4,196 feet would impound a reservoir with a total capacity of almost 7,000,000 acre-feet. When filled to capacity, the reservoir would extend 50 miles upstream and would cover an area of 70,000 acres. An 80,000-kilowatt plant at the site could produce nearly 500,000,000 kilowatt-hours of energy with initial flow conditions and about 250,000,000 kilowatt-hours with ultimate flow conditions. The net average evaporation loss from the reservoir would amount to about 170,000 acre-feet each year. The reservoir would be so located that it could control a third of all the sediment now passing Lees Ferry. The reservoir capacity would be reduced by encroaching sediment at a rate of more than 3,000,000 acre-feet in each 100-year period. Sediment storage in a reservoir at the Chinle site would result in a corresponding reduction in the quantities of sediment deposited in the potential Glen Canyon Reservoir. Therefore, it may prove desirable to construct a temporary power and sediment storage development at the Chinle site at an early date if a practicable means can be found to minimize water losses from flood plains that would be formed by the silt beds.

Other storage and power sites are located on the Colorado River and its tributaries in the upper basin. Among these are the Blue Mountain site on the Yampa River just downstream from the confluence of the Little Snake River and the Yampa River, and the Goosenecks and Slick Horn sites on the San Juan River in the reach between the Chinle Dam site and the upstream bank of the potential Glen Canyon Reservoir. Developments at the sites mentioned could provide only limited amounts of storage and their chief function would be to produce electric energy by utilizing flows regulated upstream. Power production at the sites may be desirable at a later date since the initial energy generation at the units now included in the project plan would be materially reduced as future reclamation projects are completed.

As now planned protection is provided against sediment encroachment for about 200 years. When more complete data are assembled on sediment-contributing areas, development of reservoirs specifically for sediment control may be found desirable. Such reservoirs and improved land management and practices for reduction of erosion would increase the usefulness of the storage project by extending its life or by making available storage capacity for other purposes.

CHAPTER IV

WATER RESOURCES

Heaviest precipitation in the Upper Colorado River Drainage Basin falls as winter snow in the high mountain ranges. With the rising temperatures of late spring and early summer, the snow melts rapidly, pouring torrential flows into principal run-off channels. Run-off during April, May, June, and early July comprises more than two-thirds of the annual flow at Lee Ferry. Normally the high flow subsides by late July to near the base or minimum flow, made up of spring-fed headwater contributions, return flow from irrigation, and escaping channel storage. Large land areas below the mountains contribute little to the river flow. Their limited accretions occur only during early spring snow melt or during summer rain floods of short duration.

The period of high stream flow does not coincide with the period of greatest irrigation demand. The flows of April, May, and June are practically unused, but flows during other months of the irrigation season are insufficient for present irrigation requirements.

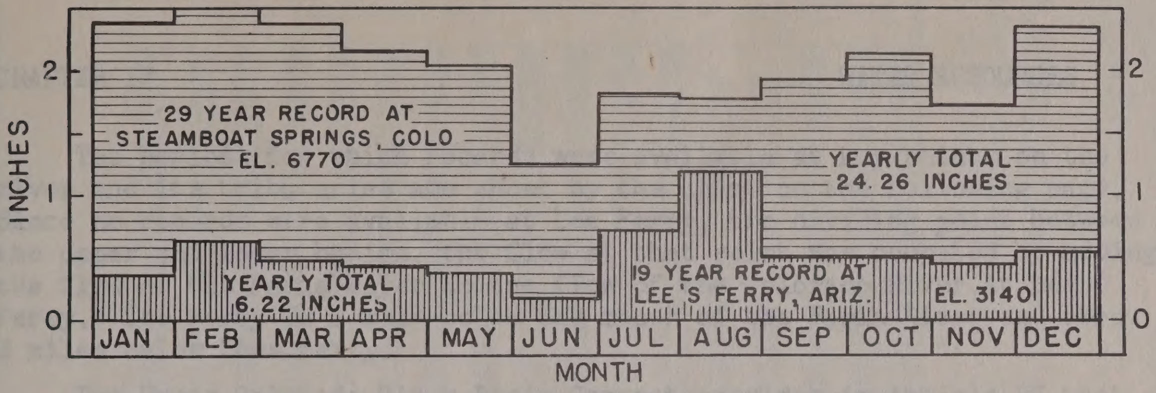
Differences between high- and low-lying areas in the upper drainage basin with respect to precipitation, temperature, and evaporation are illustrated by the chart on the following page.

Water Supply

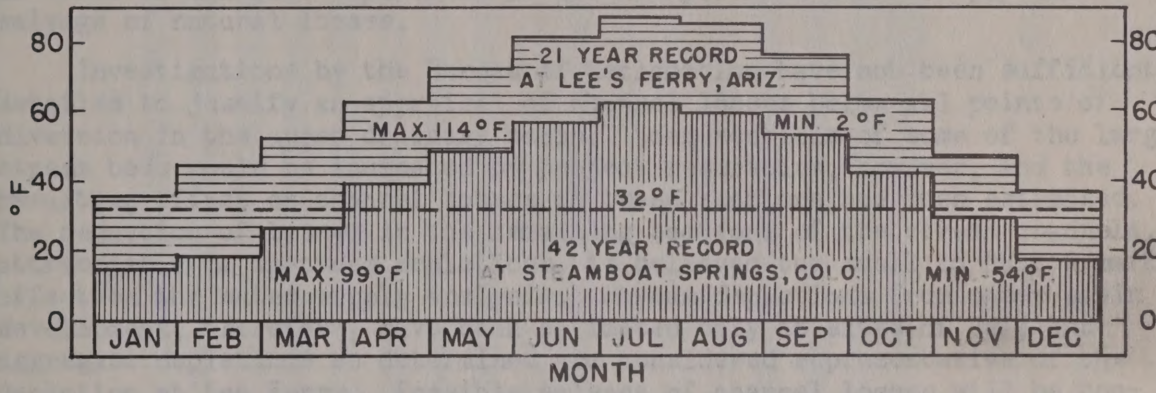
Water Supply Studies

Detailed water supply studies for the Colorado River Storage project were made for the period 1914-1947. This period of study includes the period 1914-1945 used by the Engineering Advisory Committee in its November 29, 1948, report to the Upper Colorado River Commission and was selected for two principal reasons: (1) records of stream flow at a number of main stem and tributary stations are sufficient for that period to justify the necessary extension of many other shorter records, and (2) the period includes years of above normal flow prior to 1931 and years of drouth subsequent to 1931, giving proper balance to the study.

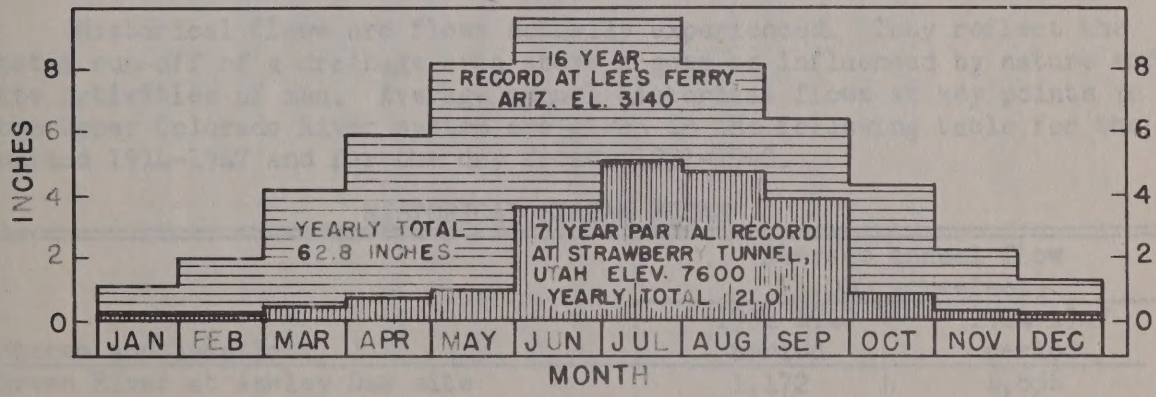
Although inaccuracies are risked with the extension of records prior to 1914, the Bureau of Reclamation made extensions to include the 1896-1947 period at Lee Ferry and the 1906-1947 period at other key points on the Colorado River system. The earlier data show a rapid recovery of stream flows following the drouth period ending in 1905. That drouth, however, was much less severe than the drouth of the 1930's.



PRECIPITATION



TEMPERATURE



EQUIVALENT RESERVOIR EVAPORATION

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER STORAGE PROJECT

PRECIPITATION, TEMPERATURE
AND EVAPORATION

DRAWN . . . H. R. S. SUBMITTED C. B. Jacobson
TRACED H. R. S. RECOMMENDED Reed Jerman
CHECKED W. B. H. . . APPROVED Clinton D. Woods

REV CBJ
JUNE 1949

SALT LAKE AREA OFFICE
JAN. 1949

594-414-3

The periods for which records were available at key points on the river and its tributaries are shown by the chart on the following page. Since no records were available at Lee Ferry, the dividing point between the upper and lower basins, the flow at that point was computed by adding the flow of the Paria River to the flow of the Colorado River at Lees Ferry. Lee Ferry is 1 mile below the mouth of the Paria River and about 2 miles below Lees Ferry.

The Upper Colorado River Basin Compact provides in Article VI that the quantity of consumptive use of water for the upper basin and for each State of the upper basin shall be determined by the inflow-outflow method in terms of man-made depletions at Lee Ferry. This infers a partial salvage of natural losses.

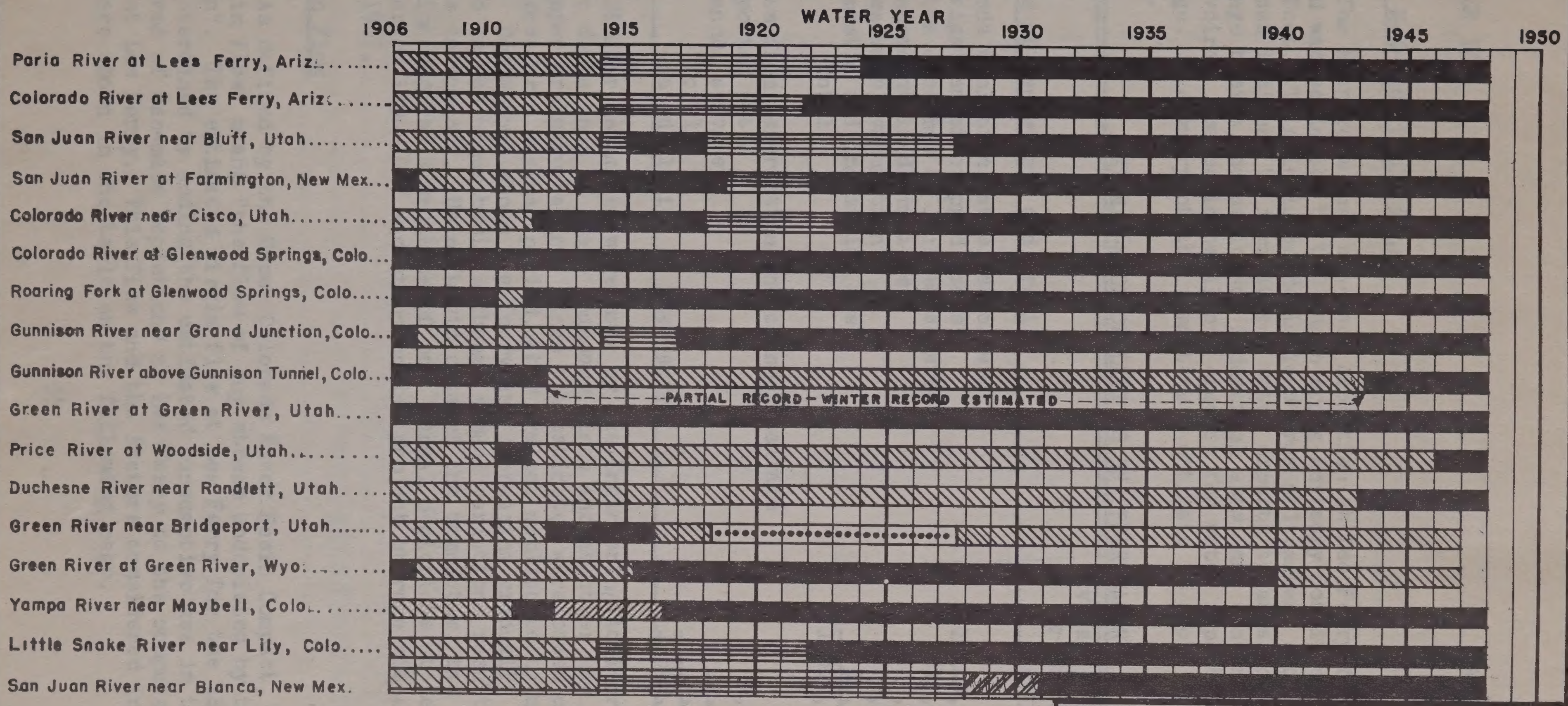
Investigations by the Bureau of Reclamation have not been sufficiently detailed to justify an appraisal of channel losses below all points of diversion in the upper drainage basin. Long sections of some of the larger stream beds would be inundated by project reservoirs, however, and the resulting effect on channel losses in these sections has been estimated. The reduction of losses in the remaining sections of the stream channels, attributable to upstream depletions, is believed too small to have a marked effect on the water supply analysis. Stream depletions from upper basin development, therefore, have been estimated only at sites of use, and aggregate depletions so determined are considered representative of the depletion at Lee Ferry. Possible salvage of channel losses will be considered in future detailed studies.

Historical Flow

Historical flows are flows actually experienced. They reflect the total run-off of a drainage area above a gage as influenced by nature and the activities of man. Average annual historical flows at key points in the Upper Colorado River system are given in the following table for the period 1914-1947 and for the dry decade 1931-1940.

HISTORICAL STREAM FLOWS

Stream and location	Average annual flow (1,000 acre-feet)	
	1931-1940 period	1914-1947 period
Green River at Ashley Dam site	1,172	1,656
Yampa River at Cross Mountain Dam site	963	1,174
Green River at Echo Park Dam site	2,530	3,298
Green River at Split Mountain Dam site	2,530	3,298
Green River at Gray Canyon Dam site	3,326	4,559
Gunnison River at Blue Mesa Dam site	873	1,131
Gunnison River at Crystal Dam site	1,012	1,310
Gunnison River at Whitewater Dam site	1,467	2,026
San Juan River at Navajo Dam site	999	1,235
Colorado River at Glen Canyon Dam site	10,126	13,607
Colorado River at Lee Ferry	10,151	13,633



- ■ Geological Survey Water Supply Papers.
- ▧ Estimated by Bureau of Reclamation.
- ▨ Colorado State Engineer (Partial record).
- ☰ Estimated by Engineering Advisory Committee and Bureau of Reclamation
- ⋯ Unpublished Records of Private Organizations.
- ▨ New Mexico State Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT

SOURCE OF HISTORICAL STREAMFLOW DATA

DRAWN... E.C.B.... SUBMITTED C. B. Jacobson
TRACED.... E.C.B.... RECOMMENDED
CHECKED.. C.H.H..... APPROVED C. D. Woods

Revised 12-50 L.E.H.

SALT LAKE CITY, JULY 50

594-414-128

Past Man-Made Depletions

The average annual man-made depletion at Lee Ferry for the 1914-1945 period was estimated by the Engineering Advisory Committee to be 1,849,800 acre-feet. This includes depletions from all causes, such as irrigation and uses incident to irrigation, water exports to areas outside of the drainage basins, domestic and industrial uses, and evaporation from storage reservoirs. The estimate allows credits for water importations and channel salvage. A summary of the Committee's estimate is shown in the following table.

NET MAN-MADE DEPLETIONS IN UPPER BASIN

Nature of depletions and credits	Average annual depletion or credit 1914-1945 (acre-feet)
Man-made depletions at sites of use	
Irrigation of cropped lands	1,449,000
Water consumed on incidental areas	315,400
Transmountain diversions	122,700
Reservoir evaporation	25,900
Domestic and industrial use	14,100
Total	1,927,100
Credits from importation and channel salvage	
Imported water	4,000
Channel salvage	73,300
Total	77,300
Net depletion at Lee Ferry	1,849,800

Similar estimates were made by the Engineering Advisory Committee of net depletions at State boundary lines and at other key locations in the upper drainage basin. Since the estimates were based on annual averages for a 32-year period, they are not applicable to any particular year. Depletions above Lee Ferry are increasing gradually as water uses expand in the upper basin although annual variations result from fluctuations in run-off. Using basic data of the committee, the Bureau of Reclamation derived a sequence of past annual depletions at Lee Ferry for the period 1896-1947 and at potential project storage sites for the period 1906-1947.

Virgin Flow

As defined by the Upper Colorado River Basin Compact, the term "virgin flow" means "the flow of any stream undepleted by the activities of man". The estimated virgin flow at Lee Ferry for the 1896-1947 period was determined by adding the estimated consumptive use in the upper basin in terms of man-made depletions at Lee Ferry to the computed historical flow at Lee Ferry. This flow and the factors considered in its computation are shown in the table on the following page.

COMPUTATION OF VIRGIN FLOW AT LEE FERRY

Unit : 1,000 acre-feet

Water year	Historical flow at Lee Ferry (includes Paria R.) 1/	Irrigated areas upper drainage basin (1,000 acres)	Correction factor for variation of annual water supply 2/	Depletion rate 3/ (acre-feet per acre)	Irrigation depletions upper drainage basin	Transbasin export depletions	Total depletions (Col. 5 plus Col.6) 4/	Virgin flow Colorado River at Lee Ferry	
								Annual flow (Col. 1 plus Col.7)	Percent of 1914-1945 mean virgin flow
	1	2	3	4	5	6	7	8	9
1895									
1896	9,760	310	.82	1.06	329	--	329	10,089	64
1897	17,500	370	1.08	1.38	509	--	509	18,009	116
1898	13,300	426	.94	1.21	515	--	515	13,815	88
1899	15,250	480	1.01	1.30	624	--	624	15,874	102
1900	12,600	530	.92	1.19	628	--	628	13,228	85
1901	12,900	582	.93	1.20	682	--	682	13,582	87
1902	8,740	635	.80	1.03	653	--	653	9,393	60
1903	13,950	685	.97	1.25	855	2	857	14,807	95
1904	14,700	732	1.00	1.29	942	3	945	15,645	100
1905	15,000	780	1.01	1.31	1,020	7	1,027	16,027	102
1906	17,964	800	1.11	1.43	1,144	13	1,157	19,121	121
1907	22,003	860	1.25	1.61	1,385	14	1,399	23,402	150
1908	11,763	920	0.91	1.17	1,076	17	1,093	12,856	82
1909	21,706	970	1.24	1.60	1,552	17	1,569	23,275	149
1910	12,969	1,020	0.96	1.24	1,265	14	1,279	14,248	91
1911	14,622	1,060	1.02	1.31	1,389	17	1,406	16,028	102
1912	18,880	1,090	1.16	1.49	1,624	16	1,640	20,520	131
1913	12,994	1,130	0.96	1.24	1,401	78	1,479	14,473	93
1914	19,335	1,160	1.18	1.52	1,763	124	1,887	21,222	136
1915	12,500	1,200	0.95	1.22	1,464	63	1,527	14,027	90
1916	17,325	1,230	1.12	1.44	1,771	105	1,876	19,201	123
1917	21,893	1,260	1.27	1.63	2,054	90	2,144	24,037	154
1918	13,650	1,290	0.99	1.28	1,651	63	1,714	15,364	98
1919	10,858	1,320	0.90	1.16	1,531	73	1,604	12,462	80
1920	19,739	1,350	1.20	1.55	2,093	119	2,212	21,951	140
1921	20,715	1,370	1.24	1.60	2,192	108	2,300	23,015	147
1922	16,302	1,370	1.08	1.39	1,904	99	2,003	18,305	117
1923	16,261	1,370	1.08	1.39	1.904	104	2,008	18,269	117
1924	12,481	1,370	0.95	1.22	1,671	49	1,720	14,201	91
1925	11,341	1,370	0.92	1.19	1,630	62	1,692	13,033	83
1926	14,009	1,370	1.00	1.29	1,767	77	1,844	15,853	101
1927	16,587	1,370	1.09	1.40	1,918	111	2,029	18,616	119
1928	15,323	1,370	1,05	1.35	1,850	106	1,956	17,279	110
1929	19,223	1,370	1.19	1.53	2,096	109	2,205	21,428	137
1930	13,070	1,380	0.98	1.26	1,739	76	1,815	14,885	95
1931	6,388	1,380	0.75	0.97	1,339	42	1,381	7,769	50
1932	15,286	1,380	1.05	1.35	1,863	94	1,957	17,243	110
1933	9,745	1,380	0.86	1.11	1,532	79	1,611	11,356	73
1934	4,396	1,380	0.68	0.88	1,214	30	1,244	5,640	36
1935	9,912	1,380	0.87	1.12	1,546	91	1,637	11,549	74
1936	11,970	1,380	0.94	1.21	1,670	160	1,830	13,800	88
1937	11,897	1,380	0.94	1.21	1,670	173	1,843	13,740	88
1938	15,440	1,380	1.06	1.37	1,891	214	2,105	17,545	112
1939	9,394	1,380	0.86	1.11	1,532	153	1,685	11,075	71
1940	7,082	1,380	0.78	1.00	1,380	139	1,519	8,601	55
1941	16,052	1,380	1.08	1.39	1,918	178	2,096	18,148	116
1942	17,029	1,380	1.11	1.43	1.973	123	2,096	19,125	122
1943	11,263	1,380	0.92	1.19	1,642	198	1,840	13,103	84
1944	13,221	1,380	0.99	1.28	1,766	167	1,933	15,154	97
1945	11,545	1,380	0.93	1.20	1,656	209	1,865	13,410	86
1946	8,745	1,385	0.84	1,08	1,490	191	1,681	10,426	67
1947	13,516	1,385	1.00	1.29	1,780	177	1,957	15,473	99
Means:									
1914-45	13,789	1,351	1.00	1.29	1,737	112	1,849	15,638	100
1931-40	10,151	1,380			1,564	117	1,681	11,832	76
1906-47	14,200	1,282			1,659	99	1,758	15,958	102
1896-1947	14,040	1,142			1,470	95	1,550	15,590	100

1/ Flows of 1896-1923 period for Paria River and 1896-1921 period for Colorado River were estimated by correlation with upstream gaged records.

2/ Correction factor = $\frac{1}{2}\left(1 + \frac{\text{Annual Virgin Flow}}{\text{1914-1945 Mean Annual Virgin Flow}}\right)$. Successive approximations of virgin flow were made in order to compute the figures in Column 3. First approximation was made using annual mean and historical flow.

3/ Depletion rate: Column 3 x 1.287. $\left(1.287 = \frac{\text{1914-1945 Mean Annual Depletion Exclusive of Transbasin Exports}}{\text{1914-1945 Mean Annual Irrigated Acreage}}\right)$.

4/ Depletions from past domestic and industrial use in upper basin are considered negligible.

Present Modified Flow

The present modified flow is the flow expected at any point with all upstream existing and authorized projects in operation. It was estimated at various sites by assuming a recurrence of past water supply conditions and by deducting from historical flows for each year the depletions that would have resulted from the operation of all upstream projects constructed or authorized since that year.

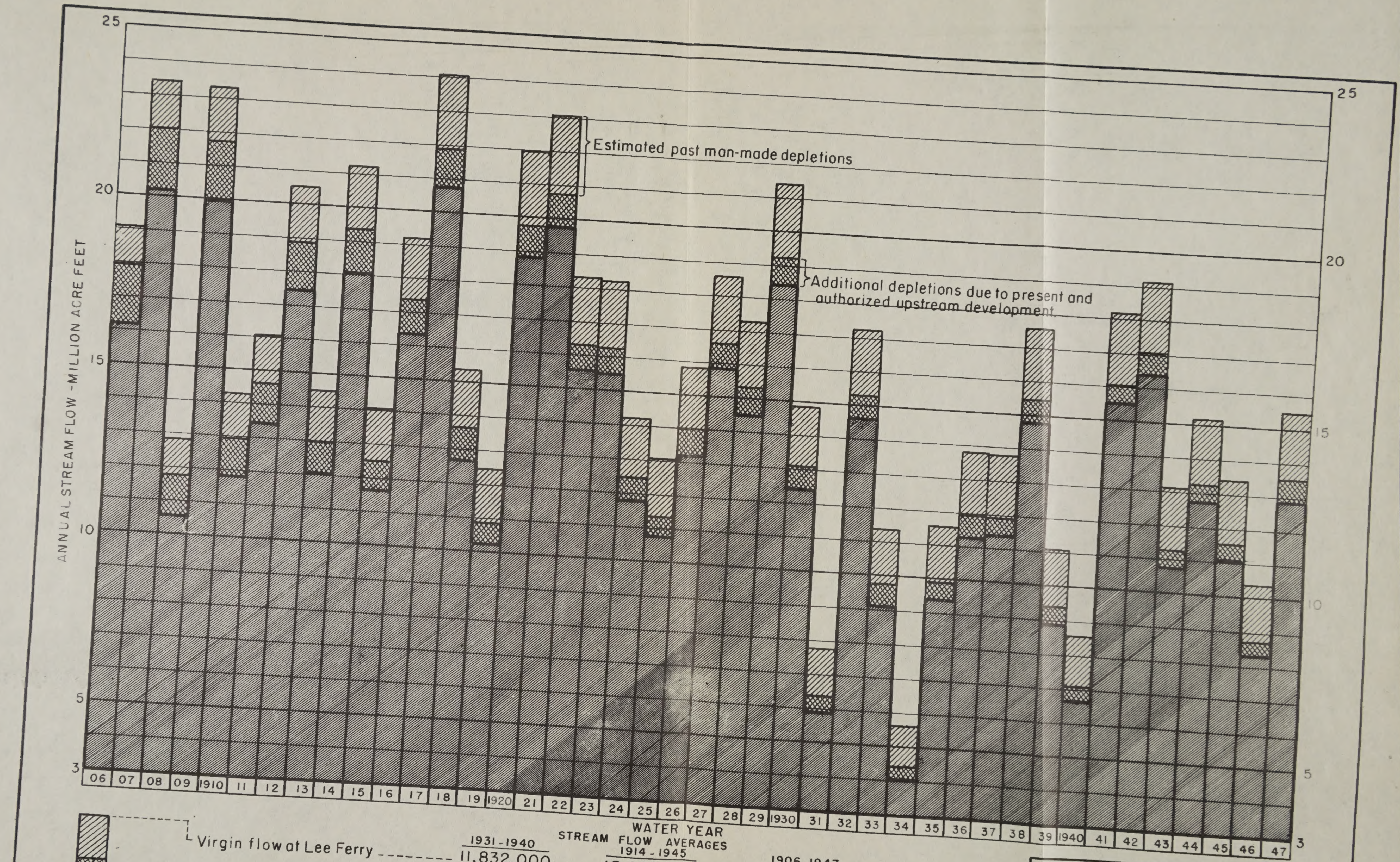
Average annual present modified flows at key points in the upper drainage basin for the period 1914-1947 and for the dry decade 1931-1940 are shown in the following table. The table on the next page shows a derivation of present modified flows of the Colorado River at Lee Ferry for each year from 1906-1947. The chart following that table compares the present modified flow at Lee Ferry with the virgin and historical flows.

AVERAGE PRESENT MODIFIED FLOW AT KEY POINTS

Site	Average annual present modified flow (1,000 acre-feet) 1931-1940 period	1914-1947 period
Green River at Ashley Dam site	1,166	1,635
Yampa River at Cross Mountain Dam site	963	1,174
Green River at Echo Park Dam site	2,523	3,274
Green River at Gray Canyon Dam site	3,279	4,471
Gunnison River at Blue Mesa Dam site	876	1,131
Gunnison River at Crystal Dam site	1,016	1,309
Gunnison River at Whitewater Dam site	1,452	2,005
San Juan River at Navajo Dam site	978	1,193
Colorado River at Glen Canyon Dam site	9,593	12,918
Colorado River at Lee Ferry	9,618	12,944

ANNUAL PRESENT MODIFIED FLOW--COLORADO RIVER AT LEE FERRY

Water year	Computed historical flow at Lee Ferry (1,000 acre-feet)	Estimated depletion from upstream projects constructed or authorized after year indicated (1,000 acre-feet)	Present modified flow at Lee Ferry (1,000 acre-feet)
1906	17,964	1,789	16,175
1907	22,003	1,845	20,158
1908	11,763	1,182	10,581
1909	21,706	1,734	19,972
1910	12,969	1,163	11,806
1911	14,622	1,195	13,427
1912	18,880	1,425	17,455
1913	12,994	935	12,059
1914	19,335	1,297	18,038
1915	12,500	880	11,620
1916	17,325	979	16,346
1917	21,893	1,135	20,758
1918	13,650	972	12,678
1919	10,858	633	10,225
1920	19,739	901	18,838
1921	20,715	970	19,745
1922	16,302	737	15,565
1923	16,261	803	15,458
1924	12,481	686	11,795
1925	11,341	580	10,761
1926	14,009	829	13,180
1927	16,587	751	15,836
1928	15,323	827	14,496
1929	19,223	801	18,422
1930	13,070	650	12,420
1931	6,388	447	5,941
1932	15,286	668	14,618
1933	9,745	634	9,111
1934	4,396	374	4,022
1935	9,912	545	9,367
1936	11,970	685	11,285
1937	11,897	488	11,409
1938	15,440	650	14,790
1939	9,394	464	8,930
1940	7,082	375	6,707
1941	16,052	531	15,521
1942	17,029	615	16,414
1943	11,263	494	10,769
1944	13,221	474	12,747
1945	11,545	485	11,060
1946	8,745	401	8,344
1947	13,516	638	12,878
Means:			
1914-45	13,789	699	13,090
1906-47	14,200	826	13,374
1931-40	10,151	533	9,618



STREAM FLOW AVERAGES

	1931-1940	1914 - 1945	1906-1947	
▨ Virgin flow at Lee Ferry	11,832,000	15,638,000	15,958,000	Acre feet.
▩ Historical flow at Lee Ferry	10,151,000	13,789,000	14,200,000	Acre feet.
▧ Present flow, modified to reflect existing and authorized upstream development.	9,618,000	13,090,000	13,374,000	Acre feet

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER STORAGE PROJECT

RIVER FLOW AT LEE FERRY

REVISED DEC. 1949 R.S.H.

DRAWN . . . HRS . . SUBMITTED J. M. Haznick . .
TRACED . . . HRS . . RECOMMENDED Leo Jerman . .
CHECKED . . SmR . . APPROVED C. D. Woods . .

SALT LAKE AREA OFFICE
MAR 1949

594-414-4

Water Available for Future Development

With completion of authorized projects, water-consuming uses would deplete the flow of the Colorado River at Lee Ferry by an estimated 2,548,000 acre-feet annually. Thus, there would remain for future development 4,952,000 acre-feet of the 7,500,000 acre-feet apportioned the upper basin by the Colorado River Compact. Present and authorized consumptive use and the use remaining for future development are shown by States in the following table. Consumptive use is estimated in terms of long-time average man-made depletions in the river flow at Lee Ferry.

PRESENT AND FUTURE CONSUMPTIVE USE, UPPER BASIN

State	Annual apportioned use (acre-feet)	Annual present and authorized use (acre-feet)	Annual use remaining for future development (acre-feet)
Arizona	50,000	11,000	39,000
Colorado	3,855,000	1,591,000	2,264,000
New Mexico	838,000	79,000	759,000
Utah	1,714,000	628,000	1,086,000
Wyoming	1,043,000	329,000 239,000	804,000
Total	7,500,000	2,548,000	4,952,000

Limitations on Future Development

Without long-time regulatory storage, the upper basin could plan to utilize only a part of the 7,500,000 acre-feet apportioned it by the Colorado River Compact since in protracted dry periods less than the compact-apportioned water would be available after the required Lee Ferry flows were provided. In the period 1931-1940, the most severe drouth decade of record, the estimated total virgin flow of the Colorado River amounted to 118,320,000 acre-feet. Thus, after meeting the 75,000,000 acre-feet Lee Ferry flow obligation provided in the compact, the upper basin would have had available for use in this 10-year period a total of only 43,320,000 acre-feet or an average of 4,332,000 acre-feet annually. Permissible consumptive use in the upper basin would have been less than this theoretical average. The quantity of water available in any 10-year period would not be known until the end of the period. In the meantime, safe operation would require that deliveries at Lee Ferry be maintained ahead of the average schedule to insure against drouth-caused shortages in the last years of the period. Upper basin use also would be curtailed in dry years by water shortages at points of diversion on tributary streams. Particularly severe shortages would have occurred in the extremely low run-off

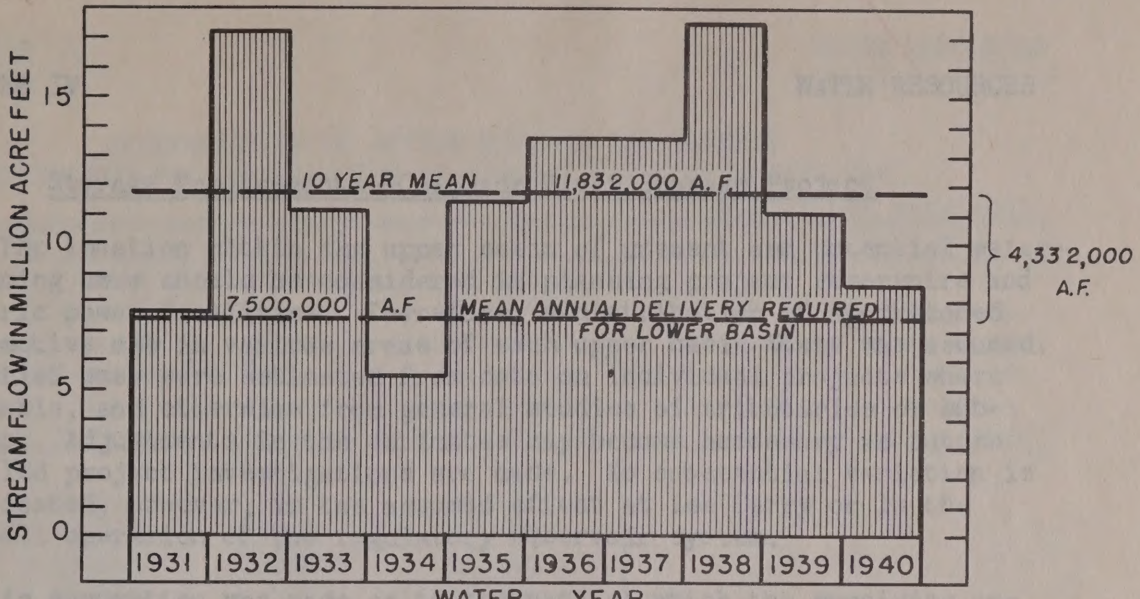
years of 1931, 1934, and 1940, as indicated graphically on the following page. If the upper basin is required to release water to Mexico during dry periods, corresponding reductions in upper basin use would be required.

Unless future drouths are much more severe than that of 1931-1940 no curtailment of present water uses in the upper basin will be required to meet the 10-year Lee Ferry flow obligation even without regulatory storage. As upper basin use increases, however, the need for regulatory storage will arise and become progressively greater. The point in upper basin development at which regulatory storage will become necessary will be determined by future run-off quantities. Through the Upper Colorado River Basin Compact, approved April 6, 1949, the States of the upper basin agreed on a division of their apportioned water and on their respective obligations with respect to the delivery of water at Lee Ferry. This made possible the formulation of a plan for basin-wide development in which all potential projects are correlated. Therefore, in the analysis in this report all projects that would consume water of the Upper Colorado River system, authorized subsequent to approval of the upper basin compact, are considered to be dependent on system regulatory storage for an assured water supply.

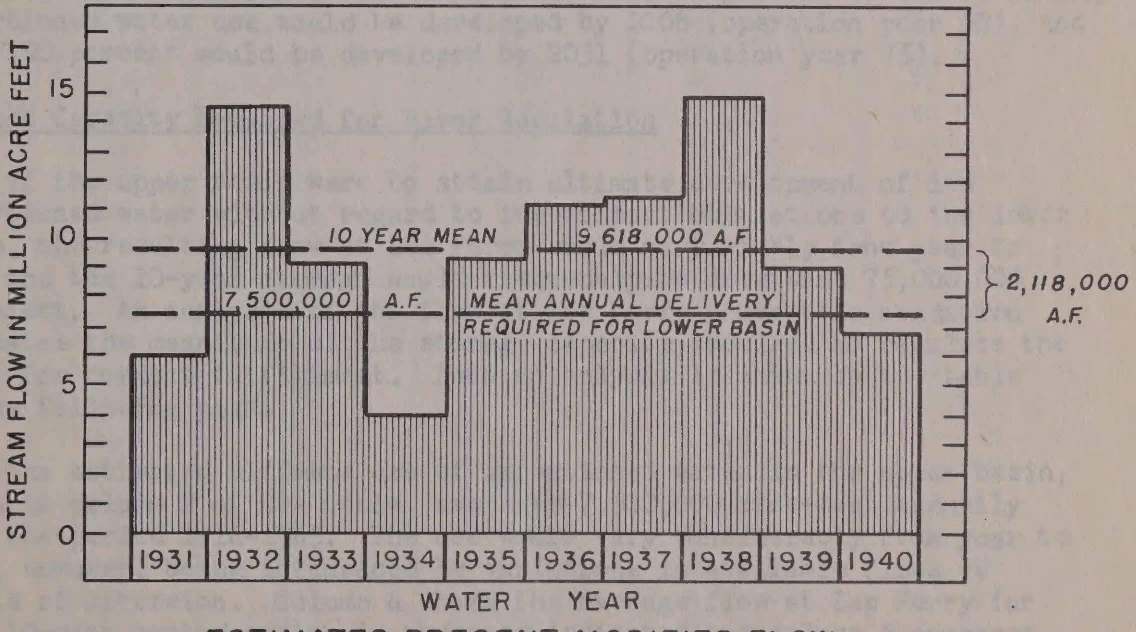
Evaporation

Increased evaporation resulting from man-made reservoirs is recognized by the upper basin States as consumptive use chargeable against the basin's water apportionment. Evaporation losses will vary from year to year, depending largely on the amount of storage provided in the basin. Estimated evaporation losses from reservoirs of the storage project are shown in the tables on reservoir operation in Chapter VI, Project Operations.

Only a few evaporation measuring pans are located in the Upper Colorado River Basin and these do not provide data directly applicable to the remote sites at which reservoirs of the Colorado River Storage project would be located. In estimating evaporation losses the Bureau used the available pan data as a base and established relationships with recorded meteorologic data. From these relationships curves were projected to indicate the gross evaporation to be expected from free water surfaces at various elevations on the Colorado River and its tributaries in the upper basin. The Engineering Advisory Committee to the Upper Colorado River Compact Commission adopted the Bureau's analysis of gross reservoir water surface evaporation. The Bureau, in computing net evaporation losses, allowed a credit for present river channel losses and other natural consumptive uses in areas to be inundated. For example, the gross evaporation rate from the free water surface of Glen Canyon Reservoir is expected to be 63 inches a year. With adjustments for present channel losses and natural consumptive uses within the reservoir area the net rate of evaporation at the maximum water surface level is estimated at 54 inches a year.



ESTIMATED VIRGIN FLOW



ESTIMATED PRESENT MODIFIED FLOW

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER STORAGE PROJECT

DROUTH CYCLE RUN-OFF AT LEE FERRY

DRAWN . . . HRS. . . SUBMITTED
TRACED . . HRS. . . RECOMMENDED Fred Jensen
CHECKED . WBH. . . APPROVED E. O. Larson

SALT LAKE AREA OFFICE
JAN 1949

594-414-5

Storage Requirements--Colorado River Storage Project

The location within the upper basin of present and potential water-consuming uses should be considered in planning project reservoirs and electric power facilities. Therefore, a distribution of apportioned consumptive use in various areas of each upper basin State was assumed. Potential uses were estimated from data on individual projects where available, and otherwise from general studies of tributaries or sub-basins. Adjustments in the estimates may become necessary as future detailed project investigations are made. No substantial variation is anticipated, however, in the assumed effect at Lee Ferry or in the over-all operation of the regulatory reservoir system.

An assumption was made as to the rate at which the remaining unused apportioned water in the upper basin would be developed. Projects now under construction or authorized for construction were considered to be in full operation by 1956, the year preceding operation year 1, resulting in stream flow depletions previously described under present modified flow conditions. It was assumed that 80 percent of the remaining apportioned water use would be developed by 2006 (operation year 50), and that 100 percent would be developed by 2031 (operation year 75).

Storage Capacity Required for River Regulation

If the upper basin were to attain ultimate development of its apportioned water without regard to its compact obligations to the lower basin, the resulting flow at Lee Ferry would vary widely from year to year and the 10-year average would frequently be less than 75,000,000 acre-feet. An analysis of the flow at Lee Ferry under this condition indicates the magnitude of the storage capacity required to regulate the river for compact fulfillment. Such an anlysis is shown by the table on the following page.

The estimated ultimate use of apportioned water in the upper basin, shown in column 2 of the table, averages 7,500,000 acre-feet annually over the period 1914-1945. The use would vary considerably from year to year, however, being influenced by variations in available flows at points of diversion. Column 4 shows the average flow at Lee Ferry for each 10-year period ending in the year indicated and column 5 compares the 10-year flow with the compact-required 75,000,000 acre-feet.

The greatest 10-year flow deficiency at Lee Ferry is shown in the table as 20,800,000 acre-feet for the period ending in 1940. More detailed studies based on monthly data rather than on the annual data used in the table indicate a deficiency of 23,000,000 acre-feet for the 1931-1940 decade, showing a need for that amount of storage capacity for river regulation.

DETERMINATION OF ACTIVE STORAGE REQUIREMENT TO PERMIT FULL UTILIZATION OF APPORTIONED CONSUMPTIVE USE

Unit: 1,000 acre-feet

	1	2	3	4	5
Water year	Virgin flow of Colorado River at Lee Ferry	Ultimate use of upper basin apportionment 1/	Ultimate depleted unregulated flow at Lee Ferry (Col.1 minus Col.2)	Ten-year moving total flow at Lee Ferry	Ten-year variation from 75 million acre-feet
1914	21,220	9,030	12,190		
1915	14,030	6,910	7,120		
1916	19,200	8,860	10,340		
1917	24,040	9,530	14,510		
1918	15,360	7,920	7,440		
1919	12,460	6,560	5,900		
1920	21,950	9,370	12,580		
1921	23,020	9,470	13,550		
1922	18,310	8,180	10,130		
1923	18,270	8,450	9,820	103,580	+28,580
1924	14,200	7,340	6,860	98,250	+23,250
1925	13,030	6,860	6,170	97,300	+22,300
1926	15,850	7,770	8,080	95,040	+20,040
1927	18,620	8,630	9,990	90,520	+15,520
1928	17,280	8,390	8,890	91,970	+16,970
1929	21,430	8,670	12,760	98,830	+23,830
1930	14,890	7,590	7,300	93,550	+18,550
1931	7,770	5,330	2,440	82,440	+ 7,440
1932	17,240	7,950	9,290	81,600	+ 6,600
1933	11,360	6,500	4,860	76,640	+ 1,640
1934	5,640	4,480	1,160	70,940	- 4,060
1935	11,550	6,450	5,100	69,870	- 5,130
1936	13,800	7,480	6,320	68,110	- 6,890
1937	13,740	6,710	7,030	65,150	- 9,850
1938	17,550	7,840	9,710	65,970	- 9,030
1939	11,080	6,260	4,820	58,030	-16,970
1940	8,600	5,130	3,470	54,200	-20,800
1941	18,150	7,700	10,450	62,210	-12,790
1942	19,120	7,830	11,290	64,210	-10,790
1943	13,100	7,070	6,030	65,380	- 9,620
1944	15,150	6,980	8,170	72,390	- 2,610
1945	13,410	6,740	6,670	73,960	- 1,040
1946	10,420	5,950	4,470	72,110	- 2,890
1947	15,470	7,510	7,960	73,040	- 1,960
Means:					
1931-40	11,830	6,410	5,420		
1914-45	15,640	7,500	8,140		

1/Use apportioned by Colorado River Compact, measured in terms of man-made depletions at Lee Ferry.

Sediment Storage Requirements

Samples of suspended sediment transported by the Colorado River and its primary upper basin tributaries have been obtained by the Geological Survey at the stations and for the periods indicated below.

Sediment sampling station	Period of sampling
Colorado River near Grand Canyon, Ariz.	1926 to 1948, inclusive
Colorado River at Lees Ferry, Ariz.	1929-1933, 1943, 1944, and 1948
Colorado River near Cisco, Utah	1930 to 1948, inclusive
San Juan River near Bluff, Utah	1930 to 1948, inclusive
Green River at Green River, Utah	1930 to 1948, inclusive

From these basic records estimates were made of sediment quantities originating above each reservoir in the Colorado River Storage project for the period 1930-1948. Eight years of simultaneous sampling at the Grand Canyon and Lees Ferry stations provided an excellent base for extending the Lees Ferry record. This record is particularly significant because it shows approximately the total amount of sediment that would be retained in all reservoirs of the Colorado River Storage project. Drainage areas above each reservoir were compared and surface geology maps studied in estimating sediment at the various storage sites.

The 1930-1948 period included a preponderance of drouth years and therefore is not representative of average stream flow and sediment conditions in the upper basin. By use of stream flow-sediment suspension relationships, however, the average sediment carried over a long-time period was estimated. Sediment loads so determined were increased 15 percent for unmeasured "bed loads." At a density of 85 pounds per cubic foot for compacted sediment the long-time average sediment deposition at Lees Ferry would approximate 100,000 acre-feet annually.

Estimated sediment deposits in each project reservoir during a 200-year period, with construction progressing as scheduled, are tabulated and illustrated graphically in the following pages.

Flood Control Storage Requirements

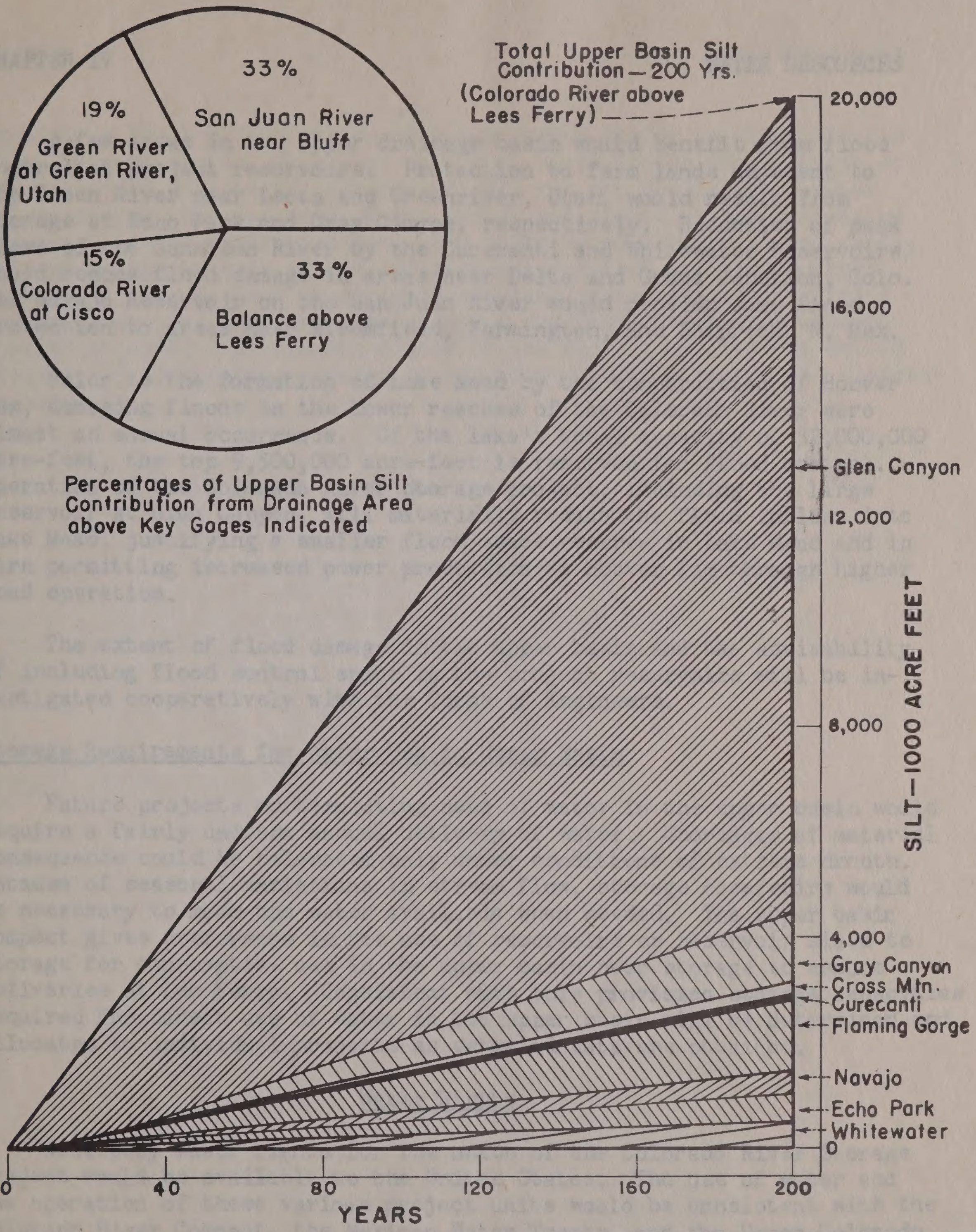
Floods on the Upper Colorado River system generally result from the rapid melting of snow in the late spring, augmented at times by heavy rains over wide tributary areas. Local flood damage frequently occurs along tributary streams but the lower reaches of the river and its major tributaries are generally confined in deep and barren canyons where floods do no damage. Most of the potential reservoir sites of the Colorado River Storage project are situated in these lower canyons so that their flood control value is limited.

SEDIMENT ENCROACHMENT IN PROJECT RESERVOIRS
(Sediment volumes at end of indicated year)

Units: 1,000 acre-feet

Year of 1/ Study	Whitewater	Echo Park	Glen Canyon	Navajo	Flaming Gorge	Curecanti	Cross Mtn.	Gray Canyon	Split Mtn. and Crystal
0	2.6								
1 1957	5.2	11.0	86.4						
2	7.8	22.0	172.8						
3	10.4	33.0	259.2						
4	13.0	37.0	343.4	2.2	7.0				Negligible
5	15.6	41.0	427.6	4.4	14.0				
6	18.2	45.0	511.8	6.6	21.0				
7	20.8	49.0	596.0	8.8	28.0				
8	23.1	53.0	680.2	11.0	35.0	.3			
9	25.4	57.0	764.4	13.2	42.0	0.6			
10	27.7	61.0	848.6	15.4	49.0	0.9			
11	30.0	65.0	932.8	17.6	56.0	1.2			
12	32.3	67.5	1017.0	19.8	63.0	1.5	1.5		
13	34.6	70.0	1101.2	22.0	70.0	1.8	3.0		
14	36.9	72.5	1185.4	24.2	77.0	2.1	4.5		
15	39.2	75.0	1262.6	26.4	84.0	2.4	6.0	7.0	
16	41.5	77.5	1339.8	28.6	91.0	2.7	7.5	14.0	
17	43.8	80.0	1417.0	30.8	98.0	3.0	9.0	21.0	
18	46.1	82.5	1494.2	33.0	105.0	3.3	10.5	28.0	
19	48.4	85.0	1571.4	35.2	112.0	3.6	12.0	35.0	
20	50.7	87.5	1648.6	37.4	119.0	3.9	13.5	42.0	
75	177	225	5,895	158	504	20	96	427	
100	235	288	7,825	213	679	28	133	602	
200	465	538	15,545	433	1,379	58	283	1,302	

1/ Year of study refers to 1956 as year 0.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT

EFFECT OF SILT CONTRIBUTION ON PROJECT RESERVOIRS

Revised 7-24-50 E.C.B.
DRAWN E.C.B SUBMITTED C.B. Jacobson
TRACED E.C.B. RECOMMENDED E.O. Larson
CHECKED C.H.H. APPROVED C.H. Carter
Dec. 49 Salt Lake City. Ut
594-414-6

A few areas in the upper drainage basin would benefit from flood control at project reservoirs. Protection to farm lands adjacent to the Green River near Leota and Greenriver, Utah, would result from storage at Echo Park and Gray Canyon, respectively. Reduction of peak flows of the Gunnison River by the Curecanti and Whitewater Reservoirs would reduce flood damage in areas near Delta and Grand Junction, Colo. The Navajo Reservoir on the San Juan River would provide some flood protection to areas near Bloomfield, Farmington, and Shiprock, N. Mex.

Prior to the formation of Lake Mead by the construction of Hoover Dam, damaging floods in the lower reaches of the Colorado River were almost an annual occurrence. Of the lake's total capacity of 32,000,000 acre-feet, the top 9,500,000 acre-feet is reserved for flood control. Operation of the Colorado River Storage project, including the large reservoir at Glen Canyon, will materially reduce the flood inflows into Lake Mead, justifying a smaller flood space reserve in Lake Mead and in turn permitting increased power production at Hoover Dam through higher head operation.

The extent of flood damage in the upper basin and the advisability of including flood control space in the project reservoirs will be investigated cooperatively with the Corps of Engineers.

Storage Requirements for Water Use in Upper Basin

Future projects contemplating uses of water in the upper basin would require a fairly uniform annual delivery of water. Shortages of material consequence could be tolerated only under conditions of extreme drouth. Because of seasonal variations in stream flow, storage reservoirs would be necessary to make the water available when needed. The upper basin compact gives preference in the use of reservoirs or reservoir sites to storage for consumptive use in the upper basin over storage to assure deliveries at Lee Ferry. Consistent with this provision storage capacities required for direct use of water in the upper basin will be determined and allocated to individual projects as detailed data are obtained.

Water Rights

Necessary water rights for the units of the Colorado River Storage project would be available to the United States. The use of water and the operation of these various project units would be consistent with the Colorado River Compact, the Mexican Water Treaty, and the Upper Colorado River Basin Compact.

Water for the various participating irrigation projects would be appropriated in accordance with the law of the State in which the point of diversion of water for each such project is located. Although the water laws of all upper basin States are fundamentally the same, the

procedures for the acquisition of water rights differ in minor details from State to State. In all of the upper basin States the doctrine of appropriation obtains and riparian rights are not recognized. Water is considered the property of the public and rights to its use can be acquired only by beneficial use. The priority of a right is ordinarily determined by the date of its initiation and "first in time is first in right". Limitations upon rights acquired in accordance with State law include: (a) the paramount right of the United States to control navigation under the commerce clause of the Constitution of the United States; (b) limitations imposed by treaties; and (c) limitations imposed by compacts.

CHAPTER V

POWER

The market area for most of the power generated by the Colorado River Storage project is shown on the map on the following page. Its principal portion includes major parts of the Upper Colorado River Drainage Basin and the adjoining Bonneville Basin on the west. This portion, which is divided into seven divisions as shown on the map, lies within the boundaries of the Bureau of Reclamation's Region 4. The market area also includes three fringe areas in the States of Wyoming, Colorado, and New Mexico that are outside the Colorado River Drainage Basin. The fringe areas are included in the Bureau of Reclamation's Regions 1, 5, 6, and 7.

Studies of the market area, made by Region 4, were based on information compiled by the Federal Power Commission and information obtained from other regions of the Bureau. Results of the studies are presented in a report, entitled Power Market Survey--Colorado River Storage Project, dated February 1949. Information from that report is included in this chapter.

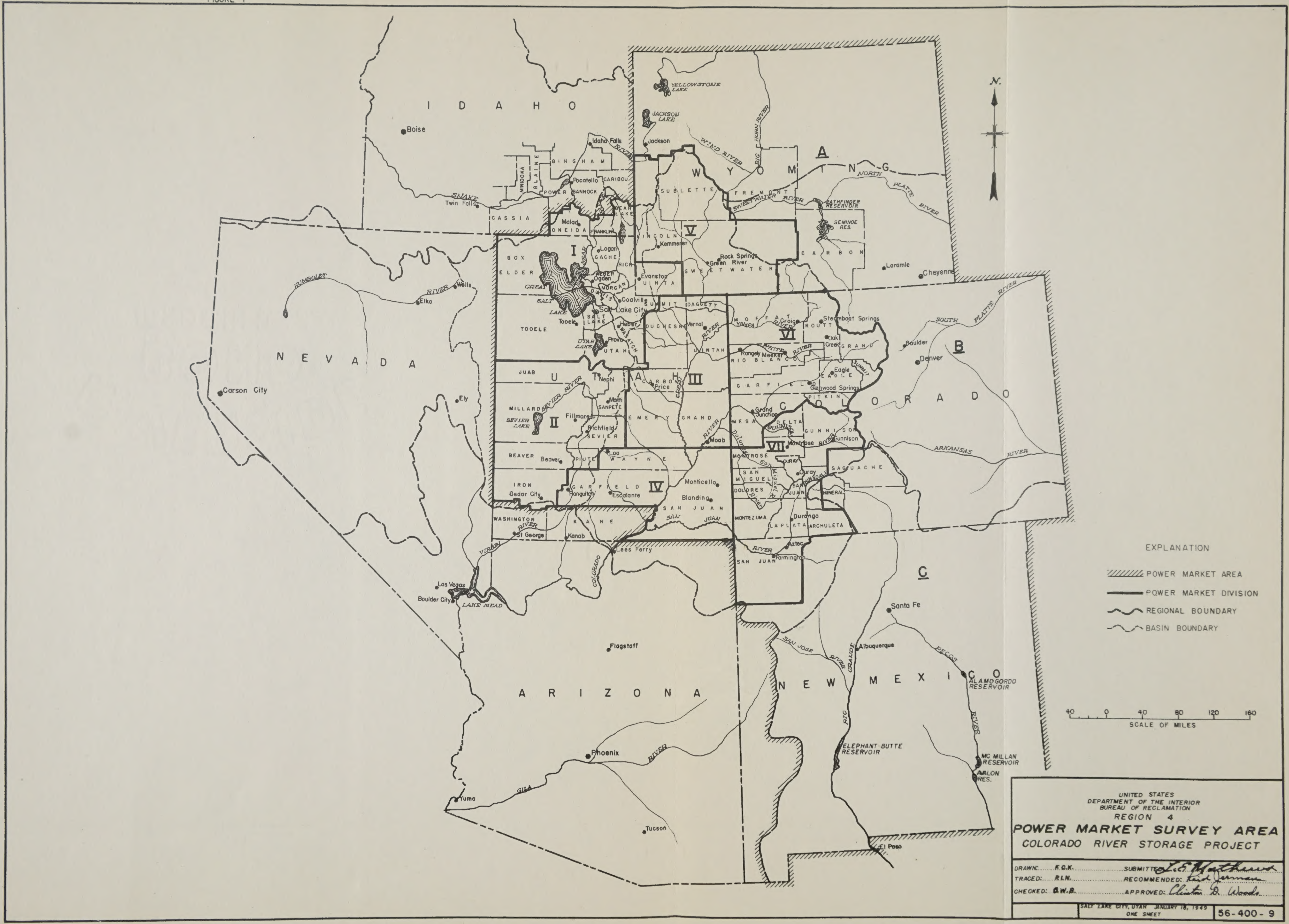
Present Development

Present Power Resources

Power resources available to the market area as of December 31, 1947, the most recent date for which such complete data are available, are summarized below.

Area	Net assured capacity 1947 (kilowatts)
Region 4	
Division I	329,679
Division II	6,485
Division III	3,920
Division IV	1,315
Division V	18,055
Division VI	41,346
Division VII	18,573
Subtotal	419,373
Fringe Areas	
A-Wyoming	85,000
B-Colorado	247,000
C-New Mexico	214,000
Subtotal	546,000
Total	965,373

FIGURE 1


IDAHO
WYOMING
UTAH
NEVADA
COLORADO
ARIZONA
NEW MEXICO
A
B
C
I
II
III
IV
V
VI
VII
N.
Boise
Idaho Falls
Pocatello
Twin Falls
Malad
Logan
Ogden
Salt Lake City
Tooele
Provo
Heber
Coalville
Evanston
Kemmerer
Rock Springs
Green River
Vernal
Nephi
Manti
Fillmore
Richfield
Beaver
Cedar City
St George
Kanab
Panguitch
Escalante
Price
Moab
Monticello
Blanding
Lees Ferry
Jackson
Laramie
Cheyenne
Craig
Steamboat Springs
Oak Creek
Rangely
Meeker
Boulder
Denver
Eagle
Glenwood Springs
Grand Junction
Delta
Montrose
Gunnison
Ouray
Durango
Aztec
Farmington
Santa Fe
Albuquerque
Las Vegas
Boulder City
Flagstaff
Phoenix
Tucson
Yuma
Carson City
Elko
Wells
Ely
El Paso
YELLOWSTONE LAKE
JACKSON LAKE
GREAT SALT LAKE
UTAH LAKE
SEVIER LAKE
BEAR LAKE
LAKE MEAD
PATHFINDER RESERVOIR
SEMINOE RES.
ALAMOGORDO RESERVOIR
ELEPHANT BUTTE RESERVOIR
MC MILLAN RESERVOIR
AVALON RES.
SNAKE RIVER
WIND RIVER
BIG HORN RIVER
SWEETWATER RIVER
NORTH PLATTE RIVER
SOUTH PLATTE RIVER
ARKANSAS RIVER
YAMPA RIVER
WHITE RIVER
GREEN RIVER
GUNNISON RIVER
DOLORES RIVER
SAN MIGUEL R.
SAN JUAN RIVER
COLORADO
VIRGIN RIVER
SEVIER RIVER
BEAR RIVER
HUMBOLDT RIVER
GILA RIVER
SAN JOSE RIVER
RIO GRANDE
PECOS RIVER
BINGHAM
BLAINE
MINIDOKA
POWER
BANNOCK
CARIBOU
CASSIA
ONEIDA
FRANKLIN
BOX ELDER
CACHE
RICH
WEBER
MORGAN
DAVIS
SUMMIT
DAGGETT
SALT LAKE
TOOELE
WASATCH
UTAH
DUCHESNE
UINTAH
JUAB
CARBON
MILLARD
SANPETE
SEVIER
EMERY
GRAND
BEAVER
PIUTE
WAYNE
IRON
GARFIELD
SAN JUAN
WASHINGTON
KANE
SUBLETTE
LINCOLN
UINTA
SWEETWATER
FREMONT
CARBON
MOFFAT
ROUTT
RIO BLANCO
GRAND
SUMMIT
EAGLE
GARFIELD
PITKIN
MESA
DELTA
GUNNISON
MONTROSE
SAN MIGUEL
OURAY
DOLORES
SAN JUAN
HINSDALE
SAGUACHE
MINERAL
MONTEZUMA
LA PLATA
ARCHULETA
LOA
EXPLANATION
POWER MARKET AREA
POWER MARKET DIVISION
REGIONAL BOUNDARY
BASIN BOUNDARY
40
0
40
80
120
160
SCALE OF MILES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 4

POWER MARKET SURVEY AREA

COLORADO RIVER STORAGE PROJECT

DRAWN: F.C.K.
TRACED: R.L.N.
CHECKED: B.W.B.
SUBMITTED: L. E. Matthews
RECOMMENDED: Reid Jerman
APPROVED: Clinton D. Woods

SALT LAKE CITY, UTAH JANUARY 18, 1949
ONE SHEET

56-400-9

Some of the energy presently available to the northern part of the Bonneville Basin is imported from systems in Montana and Idaho which in turn are interconnected with other power systems of the Pacific Northwest. Agencies operating in the Pacific Northwest estimate that power demands there will increase so rapidly that continuation of energy exports to the Bonneville Basin cannot be assured.

Present Energy Requirements

Energy requirements in the market area for the year 1947 were as shown below.

Area	Energy requirements (millions of kilowatt-hours) 1947
Region 4	
Division I	1,699
Division II	67
Division III	108
Division IV	5
Division V	75
Division VI	105
Division VII	85
Subtotal	2,144
Fringe Areas	
A-Wyoming	354
B-Colorado	1,206
C-New Mexico	901
Subtotal	2,461
Total	4,605

Future Energy Requirements

Energy requirements are rapidly increasing throughout the market area. The growing industrialization of the West, the accelerated development of natural resources, both mineral and agricultural, and increasing population are resulting in such an increased use of electric energy that existing generating facilities are taxed to capacity. Practically every electric utility in the market area has plans to increase its generating capacity to meet the requirements of the immediate future.

Estimated energy requirements for the years 1950, 1960, 1970, 1980, and 1990, as given in the Power Market Survey, are summarized in the tabulation on the following page.

Area	Estimated annual energy requirements (millions of kilowatt-hours) 1950	1960	1970	1980	1990
Region 4					
Division I	1,925	3,113	4,450	5,667	6,837
Division II	80	156	239	280	350
Division III	124	356	710	1,075	1,430
Division IV	9	17	28	50	75
Division V	84	235	403	560	710
Division VI	93	174	243	310	390
Division VII	88	155	220	300	370
Subtotal	2,403	4,206	6,293	8,242	10,162
Fringe Area					
A-Wyoming	499	1,289	2,448	3,734	5,075
B-Colorado	1,690	3,253	5,095	6,949	8,940
C-New Mexico	1,015	1,620	2,630	3,810	4,875
Subtotal	3,204	6,162	10,173	14,493	18,890
Total	5,607	10,368	16,466	22,735	29,052

Additional Power and Energy Needed

Estimates were made of the additional amounts of power and energy needed from Bureau of Reclamation plants in Region 4 to supplement all present and known scheduled power installations in satisfying the requirements of the power market area. These estimates are shown in the table on the following page. Scheduled installations considered included probable Bureau of Reclamation installations in the fringe areas outside of Region 4. Consideration was also given to reductions in capabilities that would result from the aging and retirement of equipment and from reductions in power importations.

Estimates of the power and energy required from the Colorado River Storage project were made by deducting from the total requirements from Bureau plants in Region 4 the capabilities of all other Bureau plants scheduled for construction in the region. Estimates made for 10-year intervals are shown in the following tabulation.

Year	Power needed (kilowatts)	Energy needed (millions of kilowatt-hours annually)
1950	0	0
1960	218,600	555
1970	1,110,300	5,051
1980	2,008,300	10,077
1990	3,308,300	16,820

ADDITIONAL POWER AND ENERGY NEEDED
FROM BUREAU OF RECLAMATION PLANTS IN REGION 4 FOR PROJECT POWER MARKET AREA

Year	Region 4 market area		Fringe Area A (Wyoming)		Fringe Area B (Colorado)		Fringe Area C (New Mexico)		Total--project market area	
	Power needed (kws.)	Energy needed (millions of kw.-hrs. annually)	Power needed (kws.)	Energy needed (millions of kw.-hrs. annually)	Power needed (kws.)	Energy needed (millions of kw.-hrs. annually)	Power needed (kws.)	Energy needed (millions of kw.-hrs. annually)	Power needed (kws.)	Energy needed (millions of kw.-hrs. annually)
1947	44,473	56	0	0	21,774	0	17,000	22	83,247	78
1950	43,878	3	0	51	24,670	290	0	0	68,548	344
1960	245,349	558	0	205	9,490	0	0	0	254,839	763
1970	736,353	3,331	124,000	1,186	140,590	429	220,000	865	1,220,943	5,811
1980	1,139,549	5,279	287,300	2,155	510,890	2,283	446,000	2,125	2,383,739	11,842
1990	1,538,549	7,199	521,600	3,492	903,890	4,274	720,000	3,620	3,684,039	18,585

Project Power Development

Project Capacities and Capabilities

The Colorado River Storage project would have a total installed capacity of 1,622,000 kilowatts. Capacities of the various units are listed below.

Unit	Installed capacity (kilowatts)
Cross Mountain	60,000
Crystal	48,000
Curecanti	54,000
Echo Park	200,000
Flaming Gorge	72,000
Glen Canyon	800,000
Gray Canyon	210,000
Navajo	30,000
Split Mountain	100,000
Whitewater	48,000
Total	1,622,000

With ultimate upstream depletions and with all units in coordinated operation, the project could produce an estimated 6,000,000,000 kilowatt-hours of firm energy annually. The generation of each unit, however, would vary from year to year depending on the water supply available and the number of other units in operation. The table on the next page shows the estimated firm generation of all units for each year of the assumed construction period; for year 20, the first year all units would be in coordinated operation; and for year 75, the year when all upstream water-consuming projects would be in operation. Estimates of the units' potential output are based on an assumed recurrence of water supply conditions of the 1914-1947 period, with appropriate adjustments made to reflect upstream depletions for the various stages of upper basin development.

Estimates have been made only of potential firm generation. Some secondary energy also may be generated in certain years of actual project operation.depending on the water supply available. The potential secondary generation cannot be determined from investigations to date as the reservoir operation studies have been based on the storage of all water not required to meet Lee Ferry flow obligations until project reservoirs are filled.

ESTIMATED ANNUAL FIRM ENERGY GENERATION BY PROJECT UNITS
(millions of kilowatt-hours)

Development year	Water year 1/	Project unit										Total
		White-water	Echo Park	Glen Canyon	Navajo	Flaming Gorge	Cure-canti	Split Mountain	Cross Mountain	Gray Canyon	Crystal	
0	1956											0
1	1957	274										274
2	1958	274	557									831
3	1959	274	608	1,710								2,592
4	1960	274	866	2,570								3,710
5	1961	274	865	3,420	171							4,730
6	1962	274	1,099	3,680	171	340						5,564
7	1963	274	1,092	4,110	171	348						5,995
8	1964	252	1,084	4,155	171	353						6,015
9	1965	259	1,077	4,175	171	358						6,040
10	1966	259	1,069	4,190	171	362	263					6,314
11	1967	258	816	4,200	171	387	275	372				6,479
12	1968	257	808	4,185	171	381	304	473				6,579
13	1969	256	800	4,220	171	376	308	470				6,601
14	1970	255	790	4,205	171	370	308	465	73			6,637
15	1971	254	890	4,220	171	365	308	459	78			6,745
16	1972	253	880	4,220	169	359	308	516	164	600		7,469
17	1973	252	880	4,245	166	354	306	511	169	1,128		8,011
18	1974	251	871	4,285	163	348	304	506	175	1,118	246	8,267
19	1975	250	1,002	4,300	160	343	302	626	331	1,290	245	8,849
20	1976	249	995	4,337	157	337	300	710	330	1,303	244	8,962
75	2031	187	677	2,992	32	105	227	441	310	826	206	6,003

1/ Year ending September 30 of year shown; based on assumed construction schedule.

Fuel-electric generating plants may be desirable to supplement hydroelectric plants of the Colorado River Storage project, particularly when the project output is reduced through upstream depletion. Energy for construction of some of the storage project features may be obtained from fuel-electric plants.

Utilization and Distribution of Project Power

The charts on the two following pages compare the amounts of project power and energy anticipated with the estimated amounts required by the States of the upper division comprising the project market area.

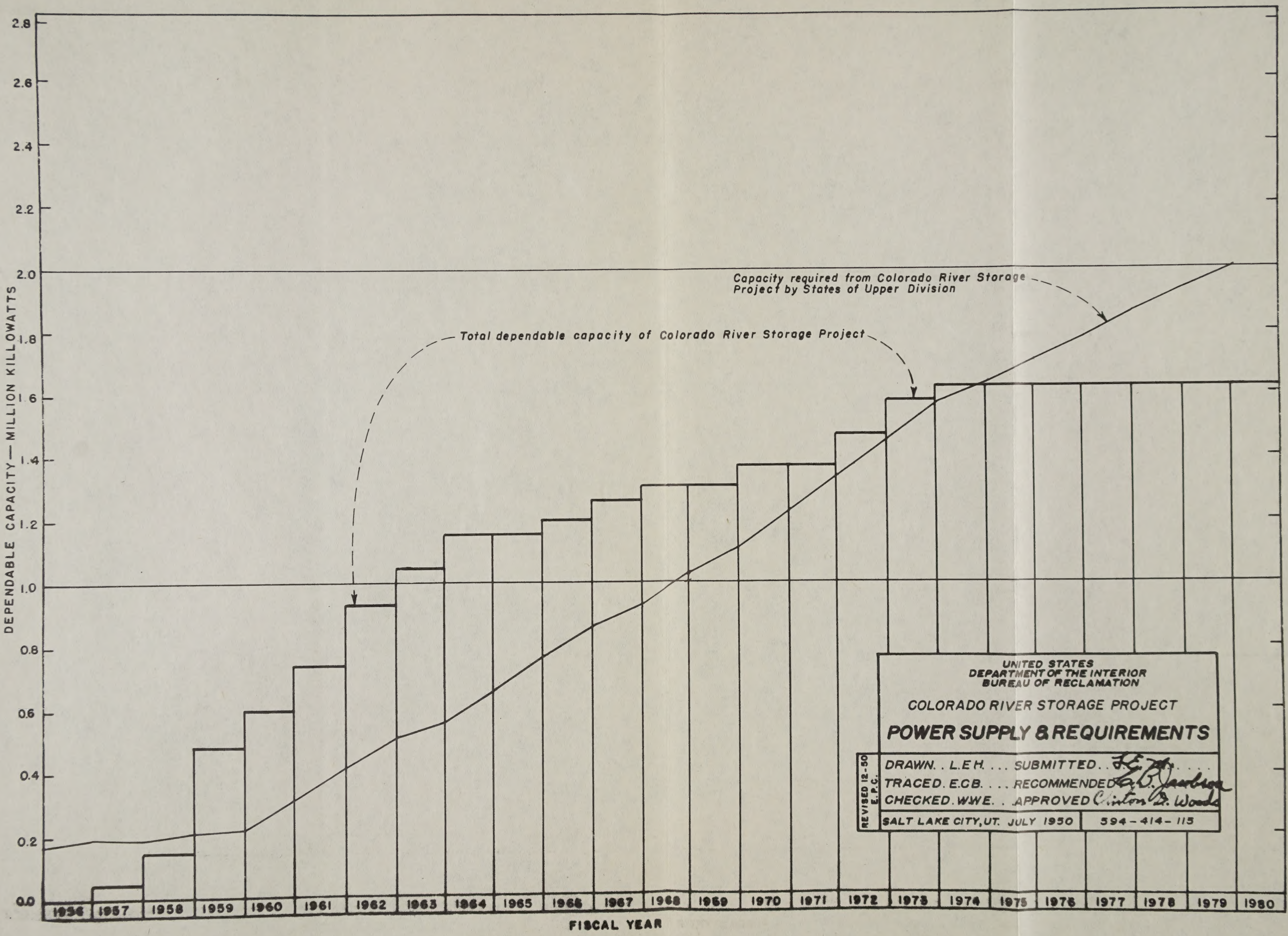
As shown by the charts, the estimated capabilities of the storage project plants in 1975 would just meet the market demands on the project in that year. By 1980 estimated energy requirements would greatly exceed the output of all production facilities.

Some project energy would be generated in advance of the market for firm energy. This energy would be produced while new generating units were being tested and while contract negotiations were in progress for the sale of firm energy. This temporary supply of energy would be saleable at a secondary rate and is expected to be readily absorbed in the States of the upper division and adjacent areas for fuel replacements and for use by industries having secondary energy needs.

Seasonal energy produced by other reclamation projects in the upper basin is expected to more than meet pumping requirements for these projects. Irrigation pumping energy, if any, required from the storage project would be only a small portion of the total energy output of the project. Sale of such a small amount of energy at low pumping rates would not materially affect project repayment.

The Glen Canyon Power Plant would provide a source of power which could be used to meet deficiencies which might arise due to use of water for reservoir filling if drought conditions should curtail power generation at other points. Any power losses below Lee Ferry caused by the project would be temporary, since the project, by regulating the river flow, would increase potential downstream power generation.

Power from the initial Echo Park unit would be used to meet demands in northwestern Colorado, southwestern Wyoming, and northern Utah. This area also would absorb power from the Flaming Gorge unit which is included in the initial program to permit early coordinated operation with the Echo Park unit. Energy from the Whitewater and Navajo units, also included in the initial program, would be required at any early date in western Colorado and northwestern New Mexico. As subsequent units are constructed, their power output would be absorbed in various sections of the market area.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

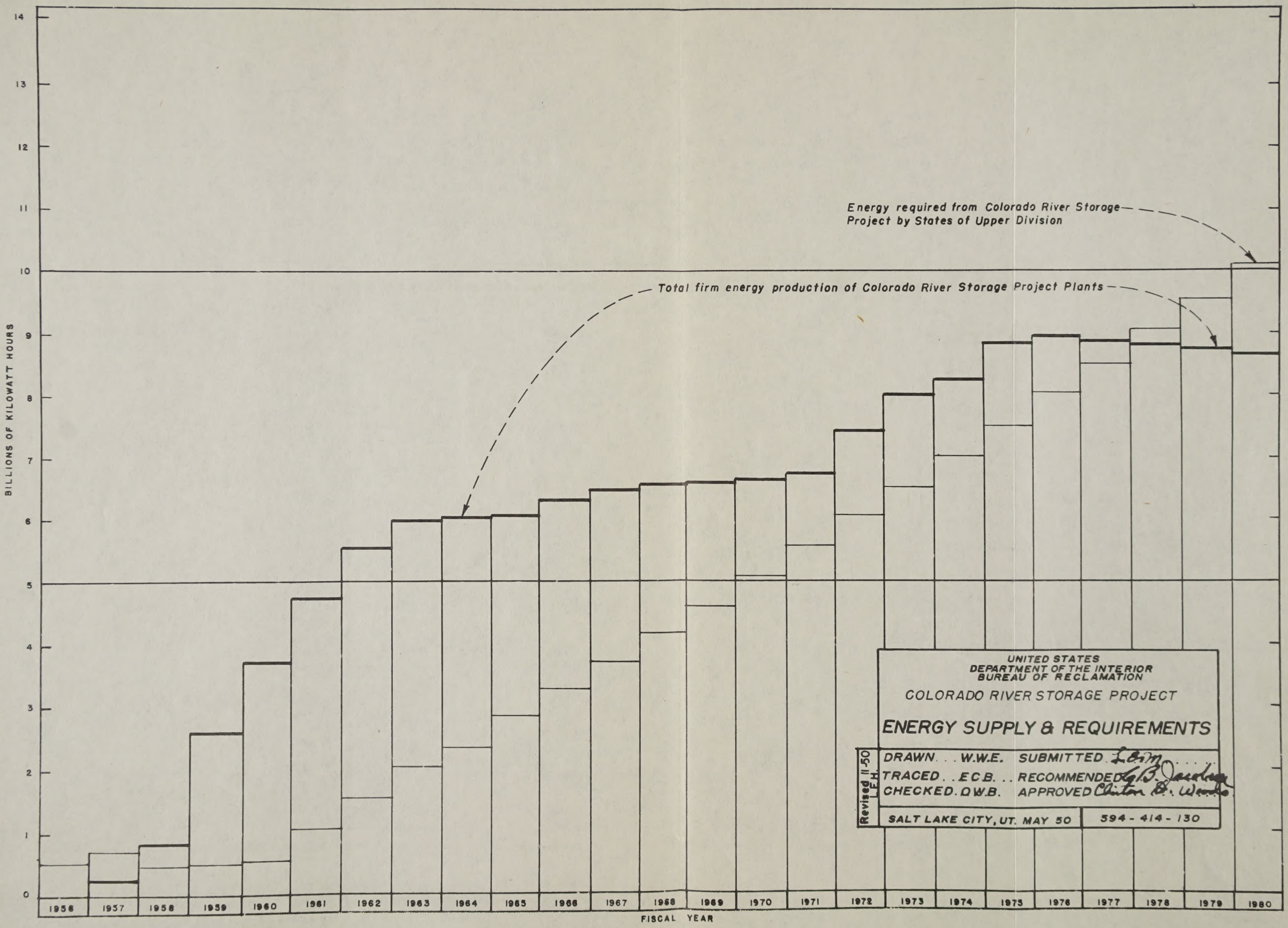
COLORADO RIVER STORAGE PROJECT

POWER SUPPLY & REQUIREMENTS

REVISED 12-50 E.P.C.

DRAWN. . L.E.H. . . . SUBMITTED. . . . . . .
TRACED. E.C.B. . . . RECOMMENDED Jacobson
CHECKED. W.W.E. . . APPROVED Clinton D. Woods

SALT LAKE CITY, UT. JULY 1950 | 594-414-115



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

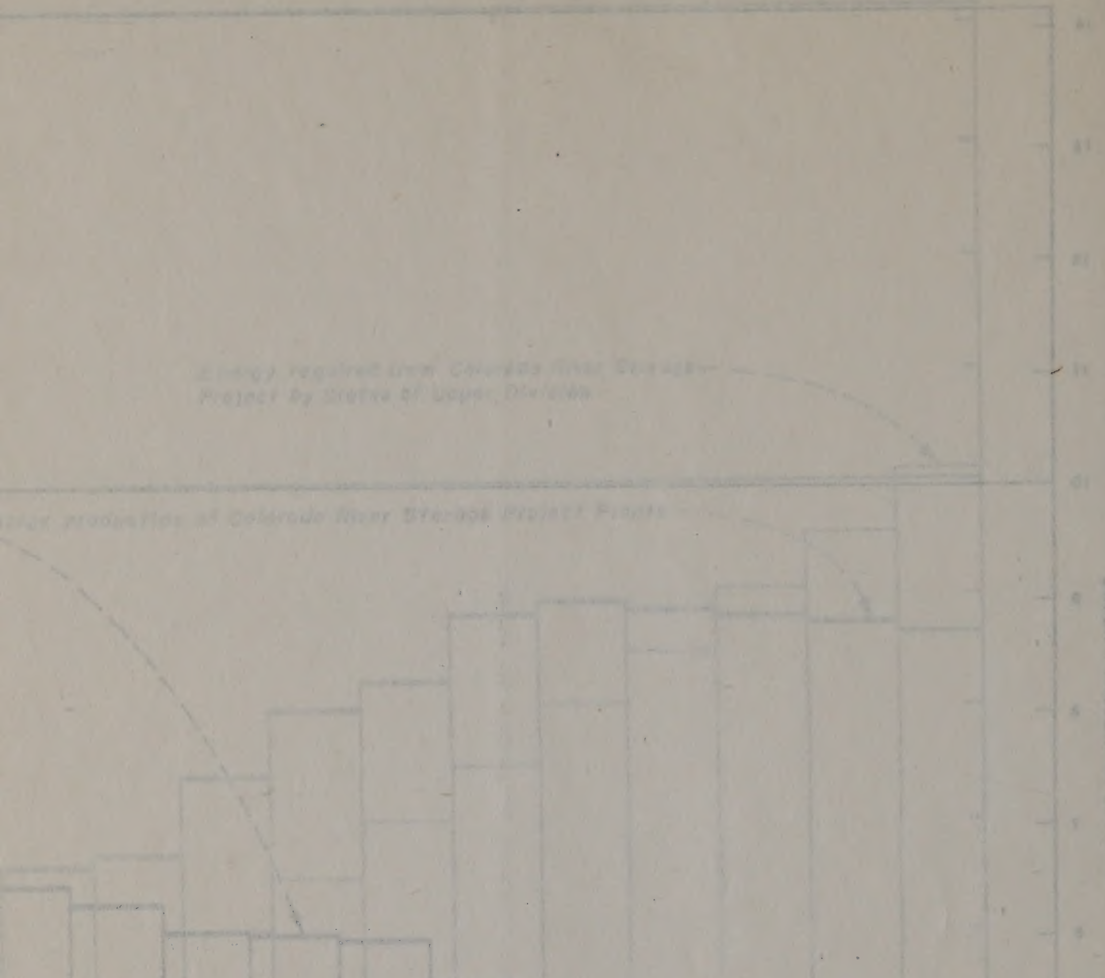
COLORADO RIVER STORAGE PROJECT

ENERGY SUPPLY & REQUIREMENTS

Revised 11-50 L.E.H.

DRAWN. . . W.W.E. SUBMITTED L.B.M.
TRACED. . E.C.B. . . RECOMMENDED G.B. Jacobson
CHECKED. Q.W.B. APPROVED Clinton D. Woods

SALT LAKE CITY, UT. MAY 50
594 - 414 - 130



Energy required from Colorado River Storage Project by States of Upper Division
…ergy production of Colorado River Storage Project Plants
BILLIONS OF KILOWATT HOURS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER STORAGE PROJECT
ENERGY SUPPLY & REQUIREMENTS
DRAWN W.W.S. SUBMITTED
TRACED E.C.B. RECOMMENDED
CHECKED C.W.A. APPROVED
SALT LAKE CITY, UTAH, MAY

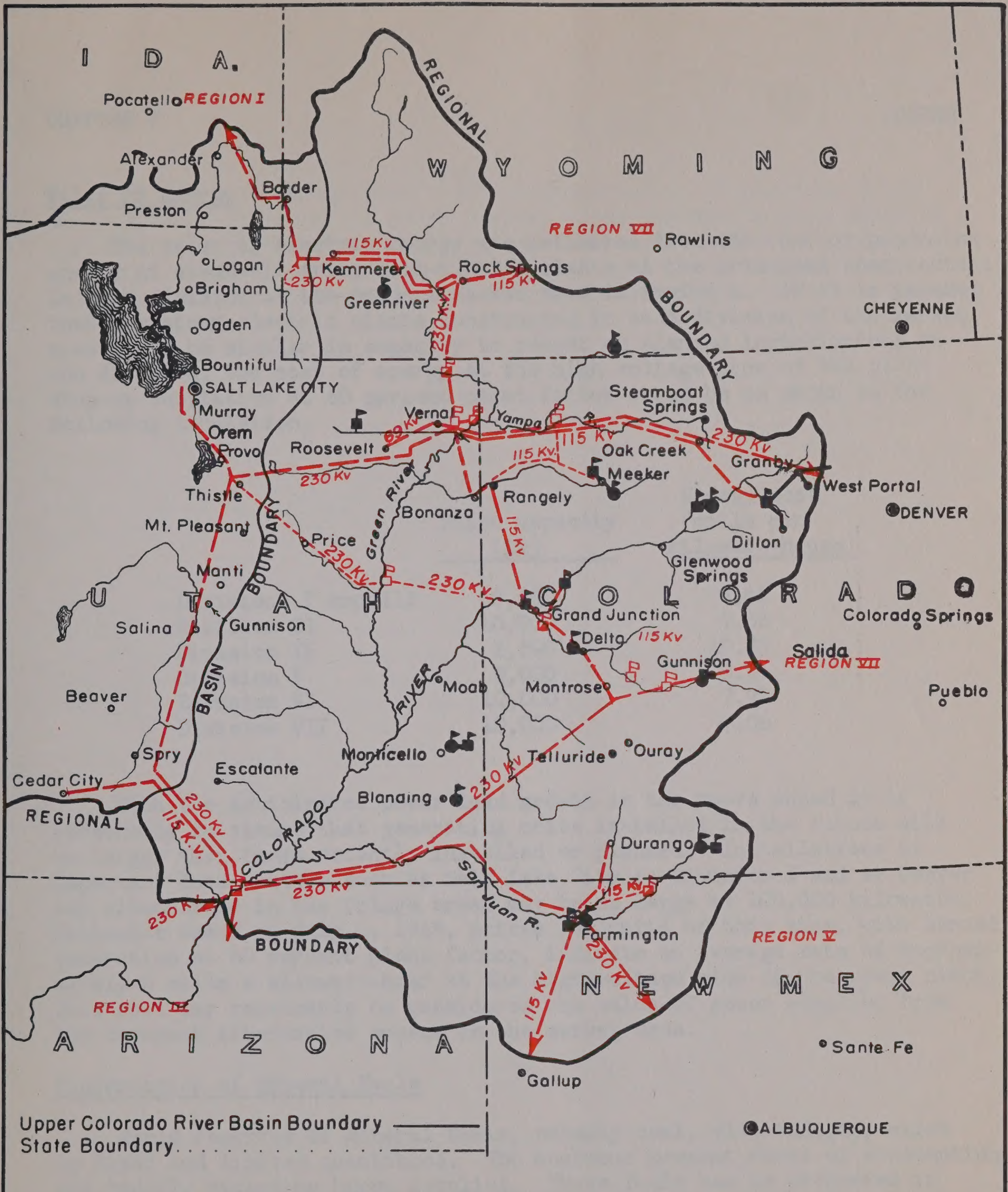
All units of the project would be operated on a coordinated basis. The plants would be interconnected to provide optimum service to the entire market area, including firming up of other power systems where needed. A backbone high-voltage system, as shown on the map on the following page, is tentatively planned to interconnect project power plants and other power installations in Region 4. Other lines are planned to permit energy from Region 4 to be interchanged with energy produced by Bureau projects in other regions in Arizona, California, Colorado, Idaho, Nevada, New Mexico, Utah, and Wyoming. Possible locations of lines to the other regions are indicated on the map by the direction of lines approaching the regional boundary. The number of lines needed for complete development and the final routing of the lines will be determined as detailed studies are completed.

Power Revenues

Ninety-three percent of the project energy is considered saleable, seven percent being allowed for transmission losses. The firm energy would be sold at an average rate of 5.5 mills a kilowatt-hour and the firm energy produced in advance of market needs would be sold at an average rate of 3 mills a kilowatt-hour.

The revenues obtained would be sufficient to pay all operation, maintenance, and replacement costs of the storage project and to retire the total project costs within 50 years after the last generating unit was placed in operation. Power revenues would include an interest charge of 3 percent on the power investment. A continuing fund in the amount of $1,000,000 is proposed to be set up from the annual operation and maintenance provisions to defray emergency expenses and to insure continuous operation of the project. Power revenues, including revenues from interest payments, that are in excess of all project costs could be used to assist in the payment of irrigation costs of participating projects. A summarized account of the estimated distribution of project revenues is given in the following tabulation and a detailed account is given in the chapter, Financial Analysis.

Total net power revenues for first 70 years		$1,814,006,800
Distribution of revenues		
Repayment of power investment	806,150,000	
Repayment of irrigation investment	332,950,000	
Excess power revenues		
Interest component	360,331,094	
Earned surplus	314,575,706	
Total		$1,814,006,800



IDA.
Pocatello
REGION I
Alexander
Border
Preston
Logan
Brigham
Ogden
Bountiful
SALT LAKE CITY
Murray
Orem
Provo
Thistle
Mt. Pleasant
Manti
Salina
Gunnison
Beaver
Spry
Cedar City
Escalante
REGIONAL
BOUNDARY
BASIN
BOUNDARY
UTAH
WYOMING
REGIONAL
BOUNDARY
REGION VII
Rawlins
CHEYENNE
Kemmerer
Greenriver
Rock Springs
115 Kv
230 Kv
230 Kv
Verna
Yampa
Roosevelt
69 Kv
230 Kv
Green River
Bonanza
Rangely
115 Kv
Meeker
Oak Creek
Steamboat Springs
115 Kv
230 Kv
Granby
West Portal
DENVER
Dillon
Glenwood Springs
COLORADO
Colorado Springs
Price
230 Kv
230 Kv
115 Kv
Grand Junction
Delta
115 Kv
Gunnison
Salida
REGION VII
Pueblo
Montrose
Moab
RIVER
Monticello
Telluride
Ouray
Blanding
230 Kv
230 Kv
115 K.V.
COLORADO
Durango
230 Kv
230 Kv
San Juan R.
115 Kv
Farmington
230 Kv
115 Kv
REGION V
NEW MEX
REGION III
ARIZONA
Gallup
Sante Fe
ALBUQUERQUE
Upper Colorado River Basin Boundary
State Boundary

GENERATING PLANTS	EXISTING	INITIAL STAGE	POTENTIAL
Hydro — Bureau of Reclamation	■	■	□
Hydro — Publicly owned	■		
Fuel — Publicly owned	●		

TRANSMISSION LINES			
Bureau of Reclamation	—	— —	- - -
Other publicly owned	—		
Interconnection			

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGION 4

COLORADO RIVER STORAGE PROJECT
TENTATIVE PROJECT POWER SYSTEM

DRAWN.. HRS.. SUBMITTED E.E.M.
TRACED.. HRS.. RECOMMENDED Reid Jerman
CHECKED. OWB.. APPROVED C. D. Woods

REV. OWB. 1-50

SALT LAKE CITY, UT. MAR. '49
ONE SHEET

594-414-7

Value of Energy

The value of electric energy was estimated from the cost of producing energy at steam-electric, coal-burning plants at the principal load centers in each division of the project market area in Region 4. If it is assumed that new steam-electric plants constructed in each division of the market area would be similar in capacity to recent or planned installations in the division, the cost of energy at the high voltage side of the plant step-up substation at 60 percent plant factor would be as shown in the following tabulation.

	Plant capacity (kw)	Energy cost (mills per kilowatt-hours)
Divisions I and III	60,000	6.61
Division II	10,000	7.56
Division IV	2,500	10.83
Division V	5,000	8.41
Division VI	10,000	7.71
Division VII	10,000	7.06

With the anticipated power load growth in the years ahead it is reasonable to assume that generating units installed in the future will be larger than those recently installed or planned. Installations at important load centers such as Salt Lake City in Division I and at Denver and Albuquerque in the fringe areas may be as large as 100,000 kilowatts. Estimates based on July 1, 1948, prices for units of this size, with annual generation at 60 percent plant factor, indicate an average rate of approximately 6 mills a kilowatt-hour at the high voltage side of the power plant. This cost may reasonably be considered the value of power supplied from the cheapest alternative source in the market area.

Conservation of Mineral Fuels

World reserves of mineral fuels, notably coal, oil, and gas, exist in fixed and limited quantities. The enormous present rates of consumption are rapidly depleting known supplies. These fuels can be preserved in their natural depositories until taken up for man's use. If little is used in this generation, more will be available for the next. The flowing water of the Colorado River cannot be preserved in this sense. Any water that flows unused to the sea today is lost forever to useful purpose.

The electric energy that could be generated in 70 years by water dropping through potential power plants of the storage project would be equivalent to that produced by burning either 225 million tons of coal, 856 million barrels of oil, or 5.6 trillion cubic feet of natural gas. These fuels, if not so consumed, could be preserved for other vital needs.

CHAPTER VI

PROJECT OPERATIONS

Reservoirs of the Colorado River Storage project would have sufficient active capacity to regulate the flow of the river to meet the Lee Ferry flow obligation even after 200 years of sediment encroachment. About 23,000,000 acre-feet of active reservoir capacity is reserved for this purpose. In addition, about 11,589,000 acre-feet of active capacity designed for sediment retention would be usable until occupied by sediment. This reservoir capacity, distributed among eight project reservoirs, would permit flexibility in storage and power operations and increased energy generation for the first 200 years of project operation.

The full utilization of water apportioned the upper basin is not expected for about 75 years. In the meantime, any water that is neither consumed in the upper basin nor required for the initial filling of project reservoirs will flow through project power plants en route to Lee Ferry. These unused flows could be regulated in project reservoirs as desired for maximum firm power generation.

Project operation studies are based on run-off conditions that occurred in the 34-year period, 1914 to 1947, inclusive. This period provides the most recent and probably the most accurate stream flow records available and it is believed to be representative of long-time conditions of run-off. The period includes a well defined cycle of precipitation with above normal run-off occurring generally in the 17-year period, 1914 to 1930, and below normal run-off occurring generally in an equal period, 1931 to 1947. It includes the driest 10-year period of record, 1931-1940, which is significant since flow obligations at Lee Ferry are based on 10-year averages. The sediment load of the river was assumed to continue at its present magnitude. Use of water apportioned the upper basin was assumed to progress uniformly in each of two stages with 80 percent of the future development being accomplished in the first 50 years and the remaining 20 percent in the last 25 years.

Project reservoir operation studies were made on a "closed-cycle" basis, meaning that water from the active regulatory capacity of all reservoirs was released as required and the capacity was refilled during the 34-year period. The regulatory capacity of the reservoirs would have been nearly full at the beginning of water year 1931 and nearly empty at the end of water year 1940 with full utilization of water apportioned the upper basin. From 1941 to 1947 partial refilling would have occurred but the period was too short to demonstrate complete refilling. The period 1914 to 1930 was used to demonstrate that the reservoirs could be completely filled under project operation.

Initial Filling of Project Reservoirs

Under the planned construction schedule and with average run-off, all project reservoirs would be constructed and filled to their aggregate capacity of 48,555,000 acre-feet within a 20-year period. During this period the system would be operated to facilitate rapid filling of the reservoirs. Water releases would be limited to those necessary to meet power market requirements and to satisfy the rights of downstream water users.

Tabulated on the following page is a summary of the operation of all project reservoirs during a 20-year period of construction and initial filling. The table shows the manner in which the reservoirs would be filled, the annual growth in firm energy generation, and the residual flows at Lee Ferry. Since variations in annual stream flows during this 20-year period cannot be foretold, average flows were assumed each year. The flows used were the averages for the 1914-1945 period, corrected for the effect of progressive development of water-consuming uses above the reservoirs and for upstream storage regulation. Sediment encroachment on reservoir capacity was considered negligible during this short period. The occurrence of protracted subnormal flows during the initial filling period would require temporary adjustments in project operation and the correlation of power operations in the upper and lower basins.

Data shown for year 20 in the initial filling tabulation differ in some aspects from those for an average year 20 in a closed-cycle operation study. In a closed-cycle study the reservoirs would not have remained full at all times so that the average evaporation would be only 810,000 acre-feet annually, compared to 1,045,000 acre-feet from full reservoirs. With less reservoir evaporation and no average annual increase in reservoir content during a closed-cycle operation the residual flow at Lee Ferry would be increased accordingly.

Initial Operation of Completed Project--Year 20

By year 20 all units of the Colorado River Storage project would be operated as an integrated system with final control of the river flow at the Glen Canyon Reservoir. Depletions at Lee Ferry from upstream uses and reservoir evaporation would then amount to about 62 percent of the use apportioned the upper basin. The maximum annual firm electric energy output for the project, estimated at 8,962,000,000 kilowatt-hours, would be attained in year 20. Thereafter the annual generation would decrease with increased upstream water depletions and with reduced reservoir capacity for the regulation of power water due to sedimentation and increasing storage requirements for river regulation. Operation of the system under conditions prevailing in year 20 to provide maximum firm energy generation would require large withdrawals from storage to supplement the below-average flows of the 1931-1940 period.

PROJECT OPERATION DURING CONSTRUCTION AND INITIAL FILLING OF RESERVOIRS

Development year	Water year 1/	Total system firm energy generation (million kwh)	Annual water utilization in upper basin (1,000 acre-feet)				Residual annual flow at Lee Ferry (1,000 acre-feet)
			Depletion exclusive of project reservoir evaporation	Project reservoir evaporation	Storage gain in project reservoirs	Total	
0	1956	0	2,548	17	880	3,445	12,193
1	1957	274	2,614	136	5,388	8,138	7,500
2	1958	831	2,679	217	5,238	8,134	7,504
3	1959	2,592	2,745	307	5,081	8,133	7,505
4	1960	3,710	2,811	462	4,874	8,147	7,491
5	1961	4,730	2,876	539	2,989	6,404	9,234
6	1962	5,564	2,942	599	2,612	6,153	9,485
7	1963	5,995	3,007	647	1,726	5,380	10,258
8	1964	6,015	3,073	689	1,711	5,473	10,165
9	1965	6,040	3,139	721	1,688	5,548	10,090
10	1966	6,314	3,204	758	1,702	5,664	9,974
11	1967	6,479	3,270	796	1,749	5,815	9,823
12	1968	6,579	3,336	844	1,762	5,942	9,696
13	1969	6,601	3,401	867	1,672	5,940	9,698
14	1970	6,637	3,467	899	1,673	6,039	9,599
15	1971	6,745	3,532	929	1,501	5,962	9,676
16	1972	7,469	3,598	944	1,363	5,905	9,733
17	1973	8,011	3,664	970	1,332	5,966	9,672
18	1974	8,267	3,729	1,007	1,234	5,970	9,668
19	1975	8,849	3,795	1,017	1,215	6,027	9,611
20	1976	8,962	3,861	1,045	1,165	6,071	9,567
Total					48,555		

1/ Year ending September 30 of year shown; based on assumed construction schedule.

The regulatory capacity of the reservoirs would not have been completely emptied, however. The annual closed-cycle project operation as of year 20 at the Glen Canyon Reservoir and the resulting flows at Lee Ferry are shown by the table on the following page.

Ultimate Project Operation--Year 75

Another closed-cycle operation study was made for year 75, when it is assumed that water uses in the upper basin, including reservoir evaporation, will result in an average annual depletion of 7,500,000 acre-feet in the flow of the Colorado River at Lee Ferry. At this stage in upper basin development the reservoir system would be operated primarily to satisfy the 10-year Lee Ferry flow obligation. The 23,000,000 acre-feet of regulatory capacity in the reservoirs would be required for that purpose. Firm electric energy generation, limited to storage releases for stream regulation, would average about 6,000,000,000 kilowatt-hours annually.

The maintenance of uniform annual flows at Lee Ferry would not be economical nor necessary to satisfy the compact requirements which are based on 10-year moving total flows. Fairly uniform annual deliveries would be made but some variations would be caused by spills beyond control of project reservoirs. With a near-constant release from the Glen Canyon Reservoir the energy generation at the Glen Canyon Power Plant would vary in relation to the hydrostatic head as determined by the reservoir water surface elevation. Through coordinated operation, however, generation at upstream power plants could be increased while the head at Glen Canyon is low, thus maintaining firm power production for the system.

The estimated long-time average annual evaporation from project reservoirs under conditions as of year 75 is shown below.

Reservoir	Average annual evaporation (acre-feet)
Whitewater	21,000
Echo Park	87,000
Glen Canyon	526,000
Navajo	16,000
Flaming Gorge	56,000
Curecanti	32,000
Split Mountain	8,000
Cross Mountain	70,000
Gray Canyon	30,000
Crystal	negligible
Total	846,000

INITIAL OPERATION OF COMPLETED PROJECT--YEAR 20
Final Point of Control at Glen Canyon Reservoir

Unit --1,000 acre-feet

Water year	Inflow to Glen Canyon Reservoir[1]	Net evaporation from Glen Canyon Reservoir	Controlled release from Glen Canyon Reservoir	Reservoir content end of year[2]	Inflow below reservoir (Paria River)	Regulated flow Colorado River at Lee Ferry	
						Annual	10-year moving total
1914	14,060	440	10,870	16,660	30	10,900	
1915	11,290	470	10,720	16,760	10	10,730	
1916	13,210	500	10,830	18,640	40	10,870	
1917	15,630	560	11,570	22,140	30	11,600	
1918	10,880	590	11,080	21,350	30	11,110	
1919	8,930	530	13,680	16,070	20	13,700	
1920	13,650	440	14,500	14,780	20	14,520	
1921	15,210	480	10,400	19,110	20	10,420	
1922	12,560	540	11,110	20,020	30	11,140	
1923	11,940	550	11,730	19,680	20	11,750	116,740
1924	10,400	530	11,600	17,950	20	11,620	117,460
1925	9,940	530	11,550	15,810	30	11,580	118,310
1926	11,710	450	11,570	15,500	30	11,600	119,040
1927	13,200	470	10,330	17,900	50	10,380	117,820
1928	12,760	530	10,330	19,800	20	10,350	117,060
1929	15,680	600	10,560	24,320	30	10,590	113,950
1930	11,410	660	10,760	24,310	20	10,780	110,210
1931	7,850	630	8,790	22,740	10	8,800	108,590
1932	10,360	560	12,390	20,150	40	12,430	109,880
1933	8,910	530	9,730	18,800	20	9,750	107,880
1934	7,000	500	8,570	16,730	20	8,590	104,850
1935	9,160	430	9,780	15,680	20	9,800	103,070
1936	10,360	440	9,990	15,610	30	10,020	101,490
1937	10,710	460	9,090	16,770	30	9,120	100,230
1938	12,810	510	8,740	20,330	30	8,770	98,650
1939	10,000	590	7,470	22,270	30	7,500	95,560
1940	8,230	550	11,400	18,550	30	11,430	96,210
1941	13,070	520	11,430	19,670	30	11,460	98,870
1942	13,850	580	11,100	21,840	20	11,120	97,560
1943	9,700	570	10,290	20,680	20	10,310	98,120
1944	11,140	560	10,280	20,980	20	10,300	99,830
1945	9,770	550	10,670	19,530	20	10,690	100,720
1946	8,200	480	11,900	15,350	20	11,920	102,620
1947	10,730	400	11,770	13,910	20	11,790	105,290
Mean	11,300	520	10,780		30	10,810	

[1] Partially regulated by upstream project reservoirs.

[2] Glen Canyon Reservoir capacity reduced by 1,650,000 acre-feet of sediment accumulation in 20 years.

Annual project operation at year 75 is summarized in the table on the following page.

Project operation similar to that of year 75 would be continued after that year under the present apportionment of water to the upper basin. After year 200, however, sediment at the present rate of erosion would encroach on the reservoir capacity required for river regulation. Without other measures to control sediment, the effectiveness of the project in providing necessary river regulation would then gradually diminish.

ULTIMATE PROJECT OPERATION--YEAR 75
Final Point of Control at Glen Canyon Reservoir

Unit--1,000 acre-feet

Water year	Inflow to Glen Canyon Reservoir 1/	Net evaporation from Glen Canyon Reservoir	Controlled release from Glen Canyon Reservoir	Reservoir content end of year 2/	Inflow below reservoir (Paria River)	Regulated flow Colorado River at Lee Ferry	
						Annual	10-year moving total
1914	10,450	460	7,470	14,130	30	7,500	
1915	7,950	500	7,490	14,090	10	7,500	
1916	9,780	510	7,460	15,900	40	7,500	
1917	11,910	590	7,470	19,750	30	7,500	
1918	7,510	620	7,470	19,170	30	7,500	
1919	7,060	600	7,480	18,150	20	7,500	
1920	12,200	620	9,810	19,920	20	9,830	
1921	12,620	630	11,840	20,070	20	11,860	
1922	10,600	640	9,960	20,070	30	9,990	
1923	9,520	630	8,890	20,070	20	8,910	85,590
1924	7,820	650	7,480	19,760	20	7,500	85,590
1925	7,000	610	7,470	18,680	30	7,500	85,590
1926	8,730	620	7,470	19,320	30	7,500	85,590
1927	9,510	620	8,150	20,060	50	8,200	86,290
1928	9,820	640	9,280	19,960	20	9,300	88,090
1929	12,500	630	11,760	20,070	30	11,790	92,380
1930	8,330	640	7,690	20,070	20	7,710	90,260
1931	4,870	600	7,490	16,850	10	7,500	85,900
1932	8,440	570	7,460	17,260	40	7,500	83,410
1933	5,970	540	7,480	15,210	20	7,500	82,000
1934	4,640	480	7,480	11,890	20	7,500	82,000
1935	6,360	400	7,480	10,370	20	7,500	82,000
1936	7,250	380	7,470	9,770	30	7,500	82,000
1937	7,720	380	7,470	9,640	30	7,500	81,300
1938	9,560	400	7,470	11,330	30	7,500	79,500
1939	6,500	400	7,470	9,960	30	7,500	75,210
1940	6,180	360	7,470	8,310	30	7,500	75,000
1941	10,590	380	7,470	11,050	30	7,500	75,000
1942	11,120	480	7,480	14,210	20	7,500	75,000
1943	6,970	480	7,480	13,220	20	7,500	75,000
1944	8,350	480	7,480	13,610	20	7,500	75,000
1945	7,440	480	7,480	13,090	20	7,500	75,000
1946	6,050	440	7,480	11,220	20	7,500	75,000
1947	8,290	420	7,480	11,610	20	7,500	75,000
Mean	8,520	530	7,990		30	8,020	

1/ Partially regulated by upstream project reservoirs.

2/ Glen Canyon Reservoir capacity reduced by 5,895,000 acre-feet of sediment accumulation in 75 years.

CHAPTER VII

FINANCIAL ANALYSIS

ANNUAL BENEFITS AND COSTS

The degree to which the Colorado River Storage project would be economically justified was determined by comparing the project's National benefits and costs. For the comparison both benefits and costs were converted to average annual equivalent values. These values were computed at an interest rate of 2.5 percent over a 100-year period beginning with the first year of project operation. Costs were based on December 1949 prices, which are essentially the same as current prices, while benefits were based on the average prices expected to prevail over the next 50 to 60 years.

Annual Benefits

Tangible benefits anticipated from the Colorado River Storage project include river regulation for irrigation and other water-consuming uses, power generation, sediment retention, flood control, fish and wildlife conservation, recreation, and possibly the development of mineral resources. While all of the benefits are measurable in monetary terms, only the benefits from irrigation and power production in the upper basin were considered in the comparison. The other benefits will be evaluated as investigations progress and as additional information on the effects of the project is provided.

Irrigation Benefits

The Colorado River Storage project, by regulating water releases to the lower basin, would make possible completion of the development for irrigation and other purposes of water apportioned the upper basin. Certain project reservoirs also could provide water for direct irrigation use in the upper basin. Irrigation benefits from the storage project would be realized only with the construction of dependent irrigation projects. Dependent projects that would use water supplied directly from the reservoirs have not been investigated in sufficient detail to justify an appraisal of the benefit value of the reservoirs as a direct source of irrigation water. This benefit value, therefore, has not been included in the present analysis. It will be considered in the future as investigations progress on direct-use irrigation projects.

Before irrigation benefits resulting from flow regulation at Lee Ferry may be definitely evaluated, determination must be made as to which irrigation projects will benefit from river regulation. It has been shown that on the basis of past stream flows presently constructed or authorized projects using water in the upper basin are protected against curtailment to meet Lee Ferry obligations even without system regulation. These projects, therefore, would not benefit from the regulation provided by the storage project. It has also been shown that the stage in upper basin development at which regulatory storage will become necessary to prevent curtailment of water use is approaching, the exact time being determined by run-off conditions of the future.

The Upper Colorado River Basin Compact, approved April 6, 1949, is an important milestone in upper basin development. By defining the rights and obligations of each upper basin State with respect to the use of water in the Colorado River system, it made possible a correlated plan of development in the upper basin. Potential projects are correlated both as to water supply and finances in the plan presented in this report. It is with good reason, therefore, that all irrigation projects using water from the Upper Colorado River system authorized subsequent to approval of the upper basin compact are considered dependent on the storage project. The irrigation benefits of such projects are attributable in part to the storage project. These benefits will not be credited to the storage project in the benefit-cost analysis. Rather, and with the same effect, an appropriate part of the cost of the storage project will be assigned as a cost of the dependent projects.

Fish and Wildlife Benefits

A considerable net benefit to fish and wildlife is expected to result from project development although an exact appraisal has not yet been made by the Fish and Wildlife Service. Preliminary studies by the Service indicate that the project will cause some damage to fish and wildlife at all the reservoir sites. The loss is expected to be offset by gains, however, particularly at the Echo Park, Glen Canyon, Cross Mountain, Flaming Gorge, and Gray Canyon Reservoir sites. Only at the Curecanti site are the monetary losses expected to be greater than the gains. Facilities for the conservation and propagation of fish and wildlife that are found justified in future investigations of the Fish and Wildlife Service would be provided as a part of project development.

Sediment Retention Benefits

Benefits from sediment retention would accrue to existing and potential facilities in the lower basin. Data required for an evaluation of these benefits, however, are not yet available.

Recreation Benefits

New recreational values are expected to result from the artificial lakes, access roads, and waterways that would be developed in the rugged canyons of the Green, Yampa, and Colorado Rivers. Sufficient studies, however, have not been conducted to permit an estimate of the costs of recreational facilities and an appraisal of recreational benefits. Recreational aspects of the project are now being investigated in detail by the National Park Service, and its findings will be considered in a future benefit-cost analysis.

Flood Control Benefits

Minor benefits from flood control are expected in both the upper and lower basins. The most significant benefits in the upper basin are expected in developed areas adjacent to stream channels below project reservoirs. Capacity reserved for flood control in Lake Mead and other potential reservoirs farther upstream in the lower basin could be reduced after construction of the Colorado River Storage project. Thus production of hydroelectric energy would be increased because of greater hydrostatic heads at the power plants. An appraisal of flood control benefits has not been made for either the upper or lower basins but may be found desirable in the future.

Mineral Development Benefits

The storage project may create benefits by making water available for processing of minerals, particularly the production of oil from oil shale which is found in vast deposits in the upper drainage basin. The benefits realized would depend largely on the method selected for processing the oil shale. Some methods now being investigated require large quantities of water. Studies of the project's effect on mineral resources are being made by the Bureau of Mines.

Power Benefits

The project is expected to result in power benefits in the upper basin of $59,084,000 annually, including $35,359,000 in direct benefits and $23,725,000 in indirect benefits. Allowances were made in the estimates for expected stream flow depletions and transmission losses.

The direct benefits were measured by the gross revenues expected from the sale of usable energy that would be produced and delivered to load centers in the power market area. Anticipated power revenues are shown on the following page.

Sale of firm energy (6,346,000,000 kilowatt-hours at 5.5 mills)	$34,903,000
Sale of secondary energy (152,000,000 kilowatt-hours at 3 mills)	456,000
Total-annual direct power benefits	$35,359,000

The indirect benefits were measured by savings in cost and by increased values that would result from the distribution and utilization of electric energy generated by the project. These benefits were estimated from production costs and studies of past use of electric energy in the potential power market area. The elements considered in determining the benefits are itemized below.

The saving in production cost realized by utilities purchasing project power for resale (assumed to be passed on to the consumer)	$ 3,554,000
A proportionate share of the retailing benefits arising from resale of project power to the consumer at higher rates	17,844,000
A proportionate share in the increased value of goods and services produced by utilization of project power	2,327,000
Total--annual indirect power benefits	$23,725,000

Summary

Benefits of various kinds are anticipated from the Colorado River Storage project. Only part of the tangible benefits from irrigation and those from power have been evaluated for the benefit-cost comparison. The irrigation benefits are contingent on the construction of dependent projects and will be credited to those projects. These benefits, therefore, are not included as benefits of the storage project. They influence the benefit-cost ratio, however, since an appropriate cost of the storage project will be borne by dependent projects in benefit-cost analyses. Only power benefits, therefore, are evaluated directly for the storage project. The evaluated project benefits are estimated at $59,084,000 annually.

Annual Equivalent Costs

Federal project costs were used in computing annual equivalent costs for comparison with the benefits. Annual costs include the present worth of the estimated construction cost amortized at 2½ percent interest over the 100-year period of analysis plus the annual cost of operation, maintenance, and replacements adjusted for a 100-year period. Adjustments were made in the construction costs for interest during construction and for the present worth of the salvage value of project features at the end of the 100-year period.

Cost Assigned to Dependent Projects

In the benefit-cost analysis a part of the storage project cost is properly assignable to dependent projects that will benefit from the river regulation provided by storage project reservoirs. It was found appropriate at the present stage of investigations of dependent projects to distribute this cost among the projects in proportion to the increase in stream depletion that would result from the construction of each project. As the first step in this distribution, the utilization of water in the upper basin with and without the Colorado River Storage project was estimated as follows:

	Average annual consumptive use (acre-feet)	
Without Colorado River Storage project		
Present and authorized uses		2,548,000
Additional development with Colorado River Storage project		
Dependent projects	4,106,000	
Regulatory evaporation	846,000	
Subtotal		4,952,000
Total development		7,500,000

The lowest cost single-purpose alternative storage system that would provide holdover storage in an amount equivalent to that provided by the multiple-purpose project is a combination consisting of Cross Mountain, Echo Park, and Glen Canyon, with capacities and estimated costs as shown in the table on the following page.

LOWEST COST SINGLE PURPOSE REGULATORY SYSTEM

Reservoir	Storage capacity (1,000 acre-feet)			Estimated construction cost (thousands)	Estimated annual operation, maintenance and replacement cost (thousands)
	Gross	Sediment 200 years	Active		
Cross Mountain	6,540	300	6,240	$ 34,300	$ 36.2
Echo Park	6,460	1,900	4,560	118,300	52.9
Glen Canyon	30,000	17,800	12,200	184,900	100.1
Total	43,000	20,000	23,000	$337,500	$189.2

The alternative average annual equivalent cost, which is the minimum annual cost assignable to dependent projects, is estimated at $9,671,000. Distributed on a basis of 4,106,000 acre-feet of increased annual consumptive use, the cost amounts to approximately $2.35 an acre-foot of increased annual consumptive use of water. The alternative average annual equivalent cost includes an allowance for amortization of the construction cost of the cheapest alternative at 2½ percent interest over a 100-year period and includes annual operation, maintenance, and replacement costs of that alternative. Allowances were made in the estimates for interest during construction and salvage value.

Storage Project Costs

Items considered in determining the annual costs of the Colorado River Storage project are shown below.

Cost item	Total cost	Annual equivalent cost
Construction cost	$1,139,100,000	
Interest during construction	74,290,000	
Gross project investment	$1,213,390,000	
Less present worth of terminal salvage value	32,123,000	
Net project investment	$1,181,267,000	$32,262,600
Operation, maintenance, and replacement cost		9,732,100
Gross annual equivalent in Federal cost		$41,994,700
Less annual costs assigned to dependent projects		9,671,000
Net annual equivalent Federal cost		$32,323,700

Benefit-Cost Ratio

Annual evaluated benefits from the Colorado River Storage project ($59,084,000) would compare with the annual costs ($32,323,700) in a ratio of 1.8 to 1.0.

COST ALLOCATIONS

All costs of the Colorado River Storage project, including costs of construction, operation, maintenance, and replacements, have been allocated either to irrigation and other water-consuming uses or to power production in the upper basin. Costs of features useful for only one purpose have been allocated to that purpose as specific costs. Costs of features useful for more than one purpose have been considered joint costs and tentatively divided between irrigation and other water-consuming uses and power. Certain project reservoirs may provide some water directly to dependent projects, but pending further investigations no cost allocations have been made on this basis. No part of the project cost has been assigned to dependent projects for repayment. No allocations have been made to power production in the lower basin, silt retention, flood control, fish and wildlife conservation, or recreation. Allocations to these and other purposes may be found desirable and justified as studies are continued.

Allocation of Construction Costs

Specific construction costs, amounting to $468,900,000, have been allocated to power. Joint construction costs, amounting to $670,200,000, have been tentatively allocated to irrigation and other water-consuming uses and to power by averaging the results of the priority-of-use and alternative-justifiable-expenditure methods. This basis for distributing the project's joint costs was selected as the most suitable after a study of several methods of allocation. Tentative allocations are shown in the following table.

ALLOCATION OF CONSTRUCTION COSTS

Purpose	Specific costs	Joint Costs: Alternative-justifiable-expenditure method	Joint Costs: Priority-of-use method	Joint Costs: Average of two methods	Total allocation
Irrigation and other water-consuming uses	$ --	$328,400,000	$337,500,000	$332,950,000	$332,950,000
Power	468,900,000	341,800,000	332,700,000	337,250,000	806,150,000
Total	$468,900,000	$670,200,000	$670,200,000	$670,200,000	$1,139,100,000

Under these tentative allocations, each project purpose would be charged no more than the capitalized value of its tangible benefits and less than the cost of its cheapest single-purpose alternative development.

Since the project units would be undertaken at different times, total allocations were distributed to the various units to facilitate payment studies during the construction period. Specific costs at each unit were first identified with the purpose served. Remaining joint costs of the total project were then distributed to the various units. Separate preliminary distributions of joint costs were made in proportion to the regulatory reservoir capacity and installed generating capacity, respectively, at each unit, except that in no instance was the distribution greater than the actual joint cost of the unit. The two distributions were then averaged for the adopted cost allocation by units which is shown in the following table. This distribution by units would not be further considered after completion of the project.

DISTRIBUTION OF ALLOCATED CONSTRUCTION COSTS BY PROJECT UNITS

Unit	Total construction cost	Irrigation and other water consuming uses	Power
Cross Mountain	$ 51,000,000	$ 24,400,000	$ 26,600,000
Crystal	37,900,000	---	37,900,000
Curecanti	80,400,000	41,090,000	39,310,000
Echo Park	165,400,000	71,550,000	93,850,000
Flaming Gorge	82,700,000	41,730,000	40,970,000
Glen Canyon	363,900,000	71,920,000	291,980,000
Gray Canyon	178,400,000	45,310,000	13$\overset{3}{4}$,090,000
Navajo	63,000,000	28,270,000	34,730,000
Split Mountain	76,400,000	---	76,400,000
Whitewater	40,000,000	8,680,000	31,320,000
Total	$1,139,100,000	$332,950,000	$806,150,000

Allocation of Operation, Maintenance, and Replacement Costs

Specific operation, maintenance, and replacement costs of $9,407,000 annually have been allocated to power. Joint costs have been allocated to irrigation and other water-consuming uses and to power in the same proportion as the construction costs. These allocations are shown in the following table.

ALLOCATION OF ANNUAL OPERATION, MAINTENANCE, AND REPLACEMENT COSTS

Purpose	Specific costs	Joint costs	Total allocation
Irrigation and other water-consuming uses		$167,700	$ 167,700
Power	$9,407,000	157,400	9,564,400
Total	$9,407,000	$325,100	$9,732,100

Operation, maintenance, and replacement costs have been distributed to units for payment studies over the construction periods on the same basis as the construction costs. These distributions are shown in the following table.

DISTRIBUTION OF ALLOCATED ANNUAL OPERATION, MAINTENANCE AND REPLACEMENT COSTS BY PROJECT UNITS

Unit	Total cost	Irrigation and other water-consuming uses	Power
Cross Mountain	$ 414,700	$ 24,600	$ 390,100
Crystal	325,500	--	325,500
Curecanti	378,100	18,900	359,200
Echo Park	1,199,200	31,900	1,167,300
Flaming Gorge	483,900	22,600	461,300
Glen Canyon	4,428,600	37,300	4,391,300
Gray Canyon	1,239,300	14,800	1,224,500
Navajo	251,000	12,300	238,700
Split Mountain	659,000	--	659,000
Whitewater	352,800	5,300	347,500
Total	$9,732,100	$167,700	$9,564,400

REPAYMENT

As tentatively allocated, the entire construction cost is reimbursable. The irrigation allocation would be repayable without interest while the power allocation would be repayable on the basis of a 3 percent interest rate.

Both irrigation and power allocations would be repaid from power revenues of the storage project. The project would not directly receive revenues from irrigation or other water-consuming uses. Irrigation revenues available to participating projects would be insufficient to pay the irrigation allocations of these projects. The power revenues of the storage project would be sufficient to pay operation and maintenance costs of the entire project and retire all construction costs within 50 years after completion of the last project unit.

A detailed schedule of project repayment, based on an analysis of the annual project revenues over a 50-year period of full project operations, appears in the table on the following page.

UPPER COLORADO RIVER ACCOUNT

All scheduled power revenues from units of the Colorado River Storage project and from participating projects located within the upper drainage basin, and all scheduled net power revenues derived from the Central Utah project (initial phase) subsequent to complete reimbursement of the reimbursable costs of that project, would be credited to an account to be known as the Upper Colorado River Account. The account would be charged with all scheduled payments on the construction, operation, maintenance, and replacement costs of the Colorado River Storage project and participating projects located within the upper drainage basin which costs are allocated to power purposes or assigned to be returned from power revenues. The account would also be charged with scheduled payments on that portion of the construction cost of each participating project allocated to irrigation which is required to be so paid in order to show full reimbursement of the irrigation allocation within 50 years following a suitable development period for that project.

Under the plan sufficient charges would be made against the account to retire the total construction cost of the storage project. The power allocation would be retired within 50 years following installation of the last generating unit.

COLORADO RIVER STORAGE PROJECT
POWER SYSTEM
FINANCIAL OPERATION STUDY FOR EXAMINATION OF AVERAGE RATE AND INVESTMENT REPAYMENT FROM POWER REVENUES

NOVEMBER 30,1950

Year of Study	Fiscal Year	Generation of Electric Energy million kilowatt-hours			Operating Revenues Sales of Electric Energy			Revenue Deductions				Net Operating Revenues (Col.8-Col.12)	Income Deductions Repayment of Investment		Investment Repayment from Power Revenues Plant in Service at End of Year				Allowable Unpaid Balance		Upper Colorado River Account					Year of Study
															Interest Bearing		Interest Free				Scheduled Aggregate Project Charges					
		Firm	Firm in Excess of Market Needs	Total (Col.3 +Col.4)	Firm (5.5 Mills)	Firm Excess (3.0 Mills)	Total (Col.6+Col.7)	Provisions for Emergency Expense	Operation Maintenance & Overhead	Provision for Replacement	9+ Total (Col.10+Col.11)		Interest (3% of Col.17)	Principal (Col.13-Col.14)	Electric Plant	Balance to Be Repaid	Irrigation Plant	Balance to Be Repaid	Electric Plant	Irrigation Plant	Power	Irrigation	Total	Scheduled Aggregate Project Credits	Accumulated Net Credits	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
					$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	
0	1956														31,320,000	31,320,000	8,680,000	8,680,000	31,320,000	8,680,000						0
1	1957	255		255	1,402,500		1,402,500		207,300	145,500	352,800	1,049,700	939,600	110,100	106,270,000	106,159,900	80,230,000	80,056,400	106,270,000	80,230,000	110,100	173,600	283,700	1,049,700	766,000	1
2	1958	460	313	773	2,530,000	939,000	3,469,000		707,300	428,900	1,136,200	2,332,800	3,184,797	(851,997)	308,250,000	308,991,897	152,150,000	150,371,800	308,250,000	152,150,000	(851,997)	1,604,600	752,603	1,580,197	2,346,197	2
3	1959	1,874	537	2,411	10,307,000	1,611,000	11,918,000	125,000	2,130,300	1,334,300	3,589,600	8,328,400	9,269,757	(941,357)	330,050,000	331,733,254	152,150,000	147,328,800	330,050,000	152,150,000	(941,357)	3,043,000	2,101,643	6,226,757	8,572,954	3
4	1960	2,516	935	3,451	13,838,000	2,805,000	16,643,000	125,000	2,346,300	1,596,500	4,067,800	12,575,200	9,951,998	2,623,202	386,580,000	385,640,052	180,420,000	172,555,800	386,580,000	180,420,000	2,623,202	3,043,000	5,666,202	12,575,200	15,481,952	4
5	1961	3,164	1,235	4,399	17,402,000	3,705,000	21,107,000	125,000	2,714,500	1,957,500	4,797,000	16,310,000	11,569,202	4,740,798	449,350,000	443,669,254	222,150,000	210,677,400	449,350,000	222,150,000	4,740,798	3,608,400	8,349,198	16,310,000	23,442,754	5
6	1962	3,992	1,183	5,175	21,956,000	3,549,000	25,505,000	125,000	3,224,100	2,410,000	5,759,100	19,745,900	13,310,078	6,435,822	471,150,000	459,033,432	222,150,000	206,234,400	471,150,000	222,150,000	6,435,822	4,443,000	10,878,822	19,745,900	32,309,832	6
7	1963	4,285	1,291	5,576	23,567,500	3,873,000	27,440,500	125,000	3,440,100	2,672,200	6,237,300	21,203,200	13,771,003	7,432,197	492,850,000	473,301,235	222,150,000	201,791,400	492,850,000	222,150,000	7,432,197	4,443,000	11,875,197	21,203,200	41,637,835	7
8	1964	4,234	1,360	5,594	23,287,000	4,080,000	27,367,000	125,000	3,656,100	2,934,400	6,715,500	20,651,500	14,199,037	6,452,463	492,850,000	466,848,772	222,150,000	197,348,400	492,850,000	222,150,000	6,452,463	4,443,000	10,895,463	20,651,500	51,393,872	8
9	1965	4,728	889	5,617	26,004,000	2,667,000	28,671,000	125,000	3,656,100	2,934,400	6,715,500	21,955,500	14,005,463	7,950,037	532,160,000	498,208,735	263,240,000	233,995,400	532,160,000	263,240,000	7,950,037	4,443,000	12,393,037	21,955,500	60,956,335	9
10	1966	5,144	728	5,872	28,292,000	2,184,000	30,476,000	125,000	3,890,100	3,078,500	7,093,600	23,382,400	14,946,262	8,436,138	599,160,000	556,772,597	263,240,000	228,730,600	599,160,000	263,240,000	8,436,138	5,264,800	13,700,938	23,382,400	70,637,797	10
11	1967	5,570	456	6,026	30,635,000	1,368,000	32,003,000	0	4,288,000	3,256,800	7,544,800	24,458,200	16,703,178	7,755,022	608,560,000	558,417,575	263,240,000	223,465,800	608,560,000	263,240,000	7,755,022	5,264,800	13,019,822	24,458,200	82,076,175	11
12	1968	5,985	133	6,118	32,917,500	399,000	33,316,500		4,382,500	3,370,100	7,752,600	25,563,900	16,752,527	8,811,373	608,560,000	549,606,202	263,240,000	218,201,000	608,560,000	263,240,000	8,811,373	5,264,800	14,076,173	25,563,900	93,563,902	12
13	1969	5,421	718	6,139	29,815,500	2,154,000	31,969,500		4,382,500	3,370,100	7,752,600	24,216,900	16,488,186	7,728,714	635,160,000	568,477,488	287,640,000	237,336,200	635,160,000	287,640,000	7,728,714	5,264,800	12,993,514	24,216,900	104,787,288	13
14	1970	5,818	354	6,172	31,999,000	1,062,000	33,061,000		4,644,800	3,522,500	8,167,300	24,893,700	17,054,325	7,839,375	635,160,000	560,638,113	287,640,000	231,583,400	635,160,000	287,640,000	7,839,375	5,752,800	13,592,175	24,893,700	116,088,813	14
15	1971	5,894	379	6,273	32,417,000	1,137,000	33,554,000		4,644,800	3,522,500	8,167,300	25,386,700	16,819,143	8,567,557	748,650,000	665,560,556	332,950,000	271,140,600	748,650,000	332,950,000	8,567,557	5,752,800	14,320,357	25,386,700	127,155,156	15
16	1972	6,292	654	6,946	34,606,000	1,962,000	36,568,000		5,153,900	3,818,900	8,972,800	27,595,200	19,966,817	7,628,383	768,250,000	677,532,173		264,481,600	768,250,000		7,628,383	6,659,000	14,287,383	27,595,200	140,462,973	16
17	1973	6,699	751	7,450	36,844,500	2,253,000	39,097,500		5,352,400	4,054,200	9,406,600	29,690,900	20,325,965	9,364,935	806,150,000	706,067,238		257,822,600	806,150,000		9,364,935		16,023,935	29,690,900	154,129,938	17
18	1974	6,760	928	7,688	37,180,000	2,784,000	39,964,000		5,550,700	4,181,400	9,732,100	30,231,900	21,182,017	9,049,883		697,017,355		251,163,600			9,049,883		15,708,883	30,231,900	168,652,955	18
19	1975	7,017	1,213	8,230	38,593,500	3,639,000	42,232,500					32,500,400	20,910,521	11,589,879		685,427,476		244,504,600			11,589,879		18,248,879	32,500,400	182,904,476	19
20	1976	7,487	847	8,334	41,178,500	2,541,000	43,719,500					33,987,400	20,562,824	13,424,576		672,002,900		237,845,600			13,424,576		20,083,576	33,987,400	196,808,300	20
21	1977	7,959	311	8,270	43,774,500	933,000	44,707,500					34,975,400	20,160,087	14,815,313		657,187,587		231,186,600			14,815,313		21,474,313	34,975,400	210,309,387	21
22	1978	8,204	0	8,204	45,122,000	0	45,122,000					35,389,900	19,715,628	15,674,272		641,513,315		224,527,600			15,674,272		22,333,272	35,389,900	223,366,015	22
23	1979	8,139		8,139	44,764,500		44,764,500					35,032,400	19,245,399	15,787,001		625,726,314		217,868,600			15,787,001		22,446,001	35,032,400	235,952,414	23
24	1980	8,074		8,074	44,407,000		44,407,000					34,674,900	18,771,789	15,903,111		609,823,203		211,209,600			15,903,111		22,562,111	34,674,900	248,065,203	24
25	1981	8,011		8,011	44,060,500		44,060,500					34,328,400	18,294,696	16,033,704		593,789,499		204,550,600			16,033,704		22,692,704	34,328,400	259,700,899	25
26	1982	7,947		7,947	43,708,500		43,708,500					33,976,400	17,813,685	16,162,715		577,626,784		197,891,600			16,162,715		22,821,715	33,976,400	270,855,584	26
27	1983	7,882		7,882	43,351,000		43,351,000					33,618,900	17,328,804	16,290,096		561,336,688		191,232,600			16,290,096		22,949,096	33,618,900	281,525,388	27
28	1984	7,817		7,817	42,993,500		42,993,500					33,261,400	16,840,101	16,421,299		544,915,389		184,573,600			16,421,299		23,080,299	33,261,400	291,706,489	28
29	1985	7,752		7,752	42,636,000		42,636,000					32,903,900	16,347,462	16,556,438		528,358,951		177,914,600			16,556,438		23,215,438	32,903,900	301,394,951	29
30	1986	7,687		7,687	42,278,500		42,278,500					32,546,400	15,850,769	16,695,631		511,663,320		171,255,600			16,695,631		23,354,631	32,546,400	310,586,720	30
31	1987	7,622		7,622	41,921,000		41,921,000					32,188,900	15,349,900	16,839,000		494,824,320		164,596,600			16,839,000		23,498,000	32,188,900	319,277,620	31
32	1988	7,558		7,558	41,569,000		41,569,000					31,836,900	14,844,730	16,992,170		477,832,150		157,937,600			16,992,170		23,651,170	31,836,900	327,463,350	32
33	1989	7,493		7,493	41,211,500		41,211,500					31,479,400	14,334,965	17,144,435		460,687,715		151,278,600			17,144,435		23,803,435	31,479,400	335,139,315	33
34	1990	7,428		7,428	40,854,000		40,854,000					31,121,900	13,820,631	17,301,269		443,386,446		144,619,600			17,301,269		23,960,269	31,121,900	342,300,946	34
35	1991	7,364		7,364	40,502,000		40,502,000					30,769,900	13,301,593	17,468,307		425,918,139		137,960,600			17,468,307		24,127,307	30,769,900	348,943,539	35
36	1992	7,299		7,299	40,144,500		40,144,500					30,412,400	12,777,544	17,634,856		408,283,283		131,301,600			17,634,856		24,293,856	30,412,400	355,062,083	36
37	1993	7,234		7,234	39,787,000		39,787,000					30,054,900	12,248,498	17,806,402		390,476,881		124,642,600			17,806,402		24,465,402	30,054,900	360,651,581	37
38	1994	7,169		7,169	39,429,500		39,429,500					29,697,400	11,714,306	17,983,094		372,493,787		117,983,600			17,983,094		24,642,094	29,697,400	365,706,887	38
39	1995	7,104		7,104	39,072,000		39,072,000					29,339,900	11,174,814	18,165,086		354,328,701		111,324,600			18,165,086		24,824,086	29,339,900	370,222,701	39
40	1996	7,039		7,039	38,714,500		38,714,500					28,982,400	10,629,861	18,352,539		335,976,162		104,665,600			18,352,539		25,011,539	28,982,400	374,193,562	40
41	1997	6,975		6,975	38,362,500		38,362,500					28,630,400	10,079,285	18,551,115		317,425,047		98,006,600			18,551,115		25,210,115	28,630,400	377,613,847	41
42	1998	6,910		6,910	38,005,000		38,005,000					28,272,900	9,522,751	18,750,149		298,674,898		91,347,600			18,750,149		25,409,149	28,272,900	380,477,598	42
43	1999	6,845		6,845	37,647,500		37,647,500					27,915,400	8,960,247	18,955,153		279,719,745		84,688,600			18,955,153		25,614,153	27,915,400	382,778,845	43
44	2000	6,781		6,781	37,295,500		37,295,500					27,563,400	8,391,592	19,171,808		260,547,937		78,029,600			19,171,808		25,830,808	27,563,400	384,511,437	44
45	2001	6,716		6,716	36,938,000		36,938,000					27,205,900	7,816,438	19,389,462		241,158,475		71,370,600			19,389,462		26,048,462	27,205,900	385,668,875	45
46	2002	6,650		6,650	36,575,000		36,575,000					26,842,900	7,234,754	19,608,146		221,550,329		64,711,600			19,608,146		26,267,146	26,842,900	386,244,629	46
47	2003	6,586		6,586	36,223,000		36,223,000					26,490,900	6,646,510	19,844,390		201,705,939		58,052,600			19,844,390		26,503,390	26,490,900	386,232,139	47
48	2004	6,521		6,521	35,865,500		35,865,500					26,133,400	6,051,178	20,082,222		181,623,717		51,393,600			20,082,222		26,741,222	26,133,400	385,624,317	48
49	2005	6,456		6,456	35,508,000		35,508,000					25,775,900	5,448,712	20,327,188		161,296,529		44,734,600	806,150,000	332,950,000	20,327,188		26,986,188	25,775,900	384,414,029	49
50	2006	6,392		6,392	35,156,000		35,156,000					25,423,900	4,838,896	20,585,004		140,711,525		38,075,600	774,830,000	324,270,000	20,585,004	6,659,000	27,244,004	25,423,900	382,593,925	50
51	2007	6,360		6,360	34,980,000		34,980,000					25,247,900	4,221,346	21,026,554		119,684,971		31,590,200	699,880,000	252,720,000	21,026,554	6,485,400	27,511,954	25,247,900	380,329,871	51
52	2008	6,328		6,328	34,804,000		34,804,000					25,071,900	3,590,549	21,481,351		98,203,620		26,535,800	497,900,000	180,800,000	21,481,351	5,054,400	26,535,751	25,071,900	378,866,020	52
53	2009	6,295		6,295	34,622,500		34,622,500					24,890,400	2,946,109	21,944,291		76,259,329		22,919,800	476,100,000	180,800,000	21,944,291	3,616,000	25,560,291	24,890,400	378,196,129	53
54	2010	6,263		6,263	34,446,500		34,446,500					24,714,400	2,287,780	22,426,620		53,832,709		19,303,800	419,570,000	152,530,000	22,426,620	3,616,000	26,042,620	24,714,400	376,867,909	54
55	2011	6,230		6,230	34,265,000		34,265,000					24,532,900	1,614,981	22,917,919		30,914,790		16,253,200	356,800,000	110,800,000	22,917,919	3,050,600	25,968,519	24,532,900	375,432,290	55
56	2012	6,198		6,198	34,089,000		34,089,000					24,356,900	927,444	23,429,456		7,485,334		14,037,200	335,000,000	110,800,000	23,429,456	2,216,000	25,645,456	24,356,900	374,143,734	56
57	2013	6,165		6,165	33,907,500		33,907,500					24,175,400	224,560	7,485,334		0		11,821,200	313,300,000	110,800,000	7,485,334	2,216,000	9,701,334	24,175,400	388,617,800	57
58	2014	6,133		6,133	33,731,500		33,731,500					23,999,400	0	0				9,605,200	313,300,000	110,800,000	0	2,216,000	2,216,000	23,999,400	410,401,200	58
59	2015	6,101		6,101	33,555,500		33,555,500					23,823,400						7,389,200	273,990,000	69,710,000		2,216,000	2,216,000	23,823,400	432,008,600	59
60	2016	6,068		6,068	33,374,000		33,374,000					23,641,900						5,995,000	206,990,000	69,710,000		1,394,200	1,394,200	23,641,900	454,256,300	60
61	2017	6,036		6,036	33,198,000		33,198,000					23,465,900						4,600,800	197,590,000	69,710,000		1,394,200	1,394,200	23,465,900	476,328,000	61
62	2018	6,003		6,003	33,016,500		33,016,500					23,284,400						3,206,600	197,590,000	69,710,000		1,394,200	1,394,200	23,284,400	498,218,200	62
63	2019	5,972		5,972	32,846,000		32,846,000					23,113,900						1,812,400	170,990,000	45,310,000		1,394,200	1,394,200	23,113,900	519,937,900	63
64	2020	5,939		5,939	32,664,500		32,664,500					22,932,400						906,200	170,990,000	45,310,000		906,200	906,200	22,932,400	541,964,100	64
65	2021	5,906		5,906	32,483,000		32,483,000					22,750,900						0	57,500,000	0		906,200	906,200	22,750,900	563,808,800	65
66	2022	5,874		5,874	32,307,000		32,307,000					22,574,900							37,900,000			0	0	22,574,900	586,383,700	66
67	2023	5,841		5,841	32,125,500		32,125,500					22,393,400							0					22,393,400	608,777,100	67
68	2024	5,810		5,810	31,955,000		31,955,000					22,222,900												22,222,900	631,000,000	68
69	2025	5,777		5,777	31,773,500		31,773,500					22,041,400												22,041,400	653,041,400	69
70	2026	5,745	0	5,745	31,597,500	0	31,597,500	0	5,550,700	4,181,400	9,732,100	21,865,400	0	0		0		0	0	0	0	0	0	21,865,400	674,906,800	70
Totals		434,253	15,215	449,468	2,388,391,500	45,645,000	2,434,036,500	1,000,000	353,008,200	266,021,500	620,029,700	1,814,006,800	693,281,094	806,150,000	806,150,000	0	332,950,000	0	0	0	806,150,000	332,950,000	1,139,100,000	1,814,006,800	674,906,800	Totals

Operation, Maintenance and Overhead (Annual)	
Reservoirs & Dams	212,800
Power Plants	2,272,600
Transmission System	3,065,300
Total	5,550,700

Annual Provision for Replacement	
F.P.C. Account	
321	168,200
322a	132,600
322b	181,400
323	1,004,400
324	134,700
325	85,700
340-349	2,474,400
Total	4,181,400

ALLOCATION OF COSTS

	Power	Irrigation	Total
Dams and Reservoirs	$337,250,000	$332,950,000	$670,200,000
Power Facilities	249,900,000		249,900,000
Transmission System	219,000,000		219,000,000
Total	$806,150,000	$332,950,000	$1,139,100,000

REPAYMENT SUMMARY (FIRST 70 YEARS)

Gross Revenue		$2,434,036,500
Operation, Maintenance and Overhead	$354,008,200	
Provision for Replacement	266,021,500	620,029,700
Net Project Revenues		1,814,006,800
Repayment of Project Construction Costs		
Power Investment	806,150,000	
Irrigation Investment	332,950,000	1,139,100,000
Net Credit Upper Colorado River Account		$674,906,800

Notes:

1. Column 4. The non-firm energy considered in this column represents that energy that is not salable as "firm"under the estimated load curve at time of production. This results from the planned installation of generating units in advance of market requirements.

2. Column 9. A continuing fund subject to expenditure by the Secretary to defray emergency expenses and to insure continuous operation of the project.

3. Column 14. Interest at 3% or power investment for determination of average firm energy rate.

4. Column 20. Each unit of power investment considered to be repaid within 50 years after that unit is placed in operation.

5. Column 21. Each item of investment considered to be repaid within 50 years after the investment is made.

Credits to the Upper Colorado River Account from the revenues of the Colorado River Storage project are expected to exceed charges against the account by the storage project in cumulative amounts shown below.

Year	Net credit from Colorado River Storage project
10	$ 70,600,000
20	196,800,000
30	310,600,000
40	374,200,000
50	382,600,000
60	454,300,000
70	674,900,000

Participating Projects

Criteria, listed below, have been established for consideration in the selection of projects to participate in the Upper Colorado River Account. Under these criteria financial assistance would be given only to practicable irrigation projects. Assistance is required by nearly all potential projects in the upper basin since projects already constructed have utilized the least expensive sites and most convenient water supplies.

(a) A project, unit, or phase thereof may be eligible to participate only when and to the extent that all sources of estimated revenue directly available to said project, unit, or phase are insufficient to return its reimbursable costs during its payout period as hereafter specified in (d).

(b) It shall be a project for the use in one or more of the States designated in Article III of the Upper Colorado River Basin Compact, of water of the Upper Colorado River system, as that system is defined in such compact, the consumptive use of which is apportioned to those States by that article.

(c) Its total benefits shall exceed its total costs, including, but without limitation, any costs attributable to its direct use of the facilities of the Colorado River Storage project or any other project, and an appropriate share of the costs of the Colorado River Storage project.

(d) With anticipated revenues from irrigation, based on the irrigators' ability to pay, it shall be able to pay the operation, maintenance, and replacement costs allocated to irrigation and to pay in a period of 50 years following a suitable development period at least part of the construction costs allocated to irrigation.

by the same criteria as the non-Indian projects in order to determine the extent to which they would be assisted by the Upper Colorado River Account. Any additional assistance required by Indian irrigators would have to be provided by means other than the Upper Colorado River Account.

Water available to the upper basin is inadequate for all potential projects. Considerable study will be required of the many potentialities before a complete group of dependent projects may be chosen that have water requirements compatible with the apportionments of the respective States of the upper basin and that are in the best interests of the individual States and the Nation as a whole. Sufficient investigations have been completed, however, to permit selection of a few projects for initial construction and participation in the Upper Colorado River Account. Other participating projects will be selected on the completion of further investigations.

Several projects have been recommended cooperatively by the States of the Upper Colorado River Basin for initial participation in the Upper Colorado River Account. Each of these projects is discussed in a supplemental report.

STATEMENTS AND PROGRAMS
OF COOPERATING FEDERAL AGENCIES

GEOLOGICAL SURVEY

The Geological Survey is responsible for the collection and analysis of basic data concerning water resources, mineral resources, and general geologic conditions affecting dam and reservoir sites. It makes topographic maps of varying detail appropriate to the several planning purposes for which they are needed. It also classifies Federal lands as to their mineral, water-power and water-storage values, and in cooperation with the Bureau of Land Management supervises the development of the resources of those public lands.

Although much information on water resources of the Upper Colorado River Basin already has been collected, available records fall far short of presenting the complete understanding of water resources which will be needed for purposes of the storage plan outlined in this report, and for full utilization of the waters allocated to the respective states under the terms of the Upper Colorado River Basin compact. Detailed geologic maps and data for the Upper Colorado River Basin are inadequate, and in large areas they are entirely lacking. The topographic mapping essential for inventory of both water resources and mineral resources is likewise far from adequate. Only 11 percent of the basin is adequately mapped, and mapping is in progress in an additional 2 percent of the area.

For the purposes of this statement, the requirements for basic data are grouped as (1) data required for the Colorado River storage project and for participating and dependent projects; and (2) data required for general basin development.

Basic-data requirements for the Colorado River storage project and for participating and dependent projects

The Colorado River storage project and its dependent projects require a great variety of basic data, some of which is within the special fields of research of the Geological Survey, and some within the provinces of other agencies of the Department of Interior, and of other Federal agencies. The basic data for which the Geological Survey is normally assigned responsibility are discussed in following paragraphs.

Operation of stream-gaging stations required by interstate compacts.--The terms of the Colorado River Compact, the LaPlata River Compact, and the Upper Colorado River Basin Compact require the operation and maintenance of nearly a hundred stream-gaging stations in the upper basin, of which eighty have been installed. Several of these have been in operation for 20 years or more, and have provided much

of the basic data upon which the Colorado River storage project is founded. This is a continuing program, to be carried on throughout the construction and operation phases of the storage project. These Compact Stations will provide for the collection of factual data at index inflow stations and at outflow stations in order to determine man-made depletions of the water supply for the upper basin as measured at Lee Ferry.

Other stream gaging.--Records of stream-flow are currently being obtained at more than 200 gaging stations in Federal-State cooperative programs. It is proposed that the number of these stations be increased to about 340. Some of these basic data are essential to the Colorado River storage project, but most are required for participating and dependent projects in which the individual states are vitally interested. Basic information secured at these stations will also be required for the determination of consumptive use of water by the different states in the upper basin, as provided in the percentage allotments and in the stipulation that the measurement of use will be by the "inflow-outflow method".

Special erosion and sedimentation studies.--The Colorado River has always been outstanding in sediment transportation, and has been cited as a horrible example of land erosion and soil wastage by many writers. The sediment has been a vexing problem in the preparation of the storage project. A long-term average sediment load has been computed as 100,000 acre feet where the river leaves the upper basin, and appropriate allowances for sediment deposition have been made at each proposed reservoir site. Refinements in basic data as to sediment transport can be expected on the basis of records collected or proposed at numerous compact gaging stations.

But such records give no assurance that the rates of erosion and of sedimentation will not increase over the years, nor do we know that we can do nothing about reducing those rates. Far more research is needed before reliable predictions can be made as to sedimentation in the future, and before evaluation can be made of proposed preventive measures. The upper basin provides many excellent field laboratories for such research, and studies are proposed especially in the San Rafael River Basin, and perhaps in several minor drainage basins. Detailed geologic and hydrologic data are fundamental to any study of erosion and sedimentation. A complete analysis of the problem will involve study also of meteorological aspects, as well as soils and vegetative cover - that is, coordination of effort among the Geological Survey, the Weather Bureau, and agencies of the Department of Agriculture.

Special water-loss studies.--Increased evaporation resulting from man-made reservoirs is recognized by the upper basin states as consumptive use chargeable against the basin's water apportionment.

Thus the chargeable losses are less than the actual evaporation from a reservoir, for they are reduced by the amount of natural loss from the stream prior to reservoir construction. In the case of Glen Canyon, it has been estimated that evaporation losses would average about 63 inches annually, of which 54 inches would be chargeable to the basin. These estimates are based on very meager data as to evaporation from free water surfaces, and transfers of data from remote areas in the case of natural losses from the stream. Detailed investigations have not been made of evaporation from streams in the basin under varying conditions of turbulence, or of evapo-transpiration from riparian vegetation or from flood plains bordering the streams.

The proposed hydrologic study of Browns Park, Colorado, is pertinent because it covers an extensive area of phreatophytes that will be inundated by Echo Park reservoir. It is also a problem area, for there are losses in the flood flows of the Green River between Linwood and Jensen, Utah, which are not yet understood.

The Browns Park area appears to be one of the best in the Upper Basin for developing the techniques required for the "inflow-outflow" method of measuring stream depletions, and for making quantitative determinations of losses by evapo-transpiration and gains by ground-water inflow. The Green River and Vermillion Creek enter Browns Park via canyons where the inflow can be determined with reasonable accuracy, and the total outflow can be determined near the Gate of Lodore. Complete hydrologic mapping of Browns Park will probably yield definitive information on all hydrologic factors, which may prove useful in analyzing other areas where the individual factors cannot be segregated.

Unexplained losses of water have been reported also in the San Juan River basin. The proposed study in the vicinity of the Navajo reservoir is for the purpose of evaluating this loss, and determining the quantities that are lost by evaporation and transpiration.

Five reservoirs in the Green River basin, Wyoming, Utah and Colorado.--The purpose of the topographic and geologic mapping in the vicinities of the proposed reservoirs is to provide data essential to the construction and subsequent operation of the reservoirs, and to the development of resources in the vicinity. These maps would contain data pertinent to construction of roads and other facilities, and would show such features as landslides, faults, thickness and distribution of surficial deposits, sources of construction materials, and weathering, strength, and other physical characteristics of rock formations. Most of these areas are now covered only by reconnaissance topographic and geologic maps at small scales which are unsuited to present needs. Topographic mapping of 735 square miles is in progress in the Echo Park and Flaming Gorge reservoir areas.

The proposed ground-water studies are concerned principally with the Madison limestone and to a lesser extent the overlying Morgan formation. The Madison is cavernous in many places and gives rise to large springs in the Uinta Range. Both formations crop out in the reservoir sites of the Echo Park unit and Split Mountain unit, and warm springs rise from the Madison in the floor of Split Mountain Canyon of the Green River. In view of its generally high permeability, thorough investigation should be made of the formation throughout a broad region, in order to determine whether there is possibility of significant losses from either reservoir by seepage.

Glen Canyon reservoir and vicinity, Arizona and Utah.-- Topographic mapping of more than 2600 square miles has a high priority for the Glen Canyon project. Geologic mapping of a slightly smaller area along the Colorado and San Juan Rivers is proposed. The rocks cropping out in the reservoir area are predominantly sandstones, as shown by geologic reconnaissance. It is known that structural basins lie northwest of the reservoir site under the Kaiparowitz Plateau and also under the Henry Mountains. Ground water studies are proposed for the purpose of determining the position of the regional water table. There is also the question whether the Kaiparowitz and Henry Mountains structural basins contain significant amounts of unsaturated strata in positions where they might draw water from the Glen Canyon reservoir.

Several wells drilled in the region for oil indicate that the regional water table is at great depth below the plateaus. In the Mexican Hat field along the San Juan River, small quantities of oil were encountered in a synclinal structure, an exceptional occurrence which has been explained as due to the lack of ground water in the area. Ground-water studies are proposed for the purpose of determining the position of the regional water table. There is also the question whether the Kaiparowitz and Henry Mountains structural basins contain significant amount of unsaturated strata in positions where they might draw water from the Glen Canyon reservoir. Drilling tests at the proposed damsite indicate that the sandstones are relatively impermeable. This impermeability would insure that seepage from the reservoir must be slow, but the question remains as to what losses might be expected during a century or more of reservoir operation. An annual loss of 100,000 acre-feet could be inconsequential in the first year of operation, but might become significant as the Colorado River waters become fully appropriated.

The Glen Canyon reservoir will extend upstream into Cataract Canyon, where gypsum and salt of the Paradox formation crop out near river level in several places. The possible effect of these rocks upon the quality of water in the reservoir should be investigated. The situation may be parallel to that at Lake Mead, where soluble rocks in the reservoir area (particularly in Las Vegas Wash) are being progressively dissolved

as the reservoir alternately inundates and exposes them. The content of dissolved solids in water flowing out of Lake Mead is appreciably greater than in the entering water.

Navajo reservoir and vicinity, New Mexico.--This includes an area of the San Juan River basin that is largely unmapped. Topographic and geologic mapping of an area of about 600 square miles is proposed. A major part of the topographic mapping is already under way. Ground-water studies are proposed in the area down stream from this reservoir, including the areas near Farmington where the water is used for irrigation.

Reservoirs in the Gunnison River basin, Colorado.--Topographic and geologic mapping of an area of about 1100 square miles is proposed. A major part of the topographic mapping is under way. This would include the areas of the Whitewater, Crystal and Curecanti units. Ground-water studies are proposed in the Delta-Montrose area and in other small areas in the basin where there appear to be possibilities of ground-water development.

Ground water in the Uinta Basin.--The Uinta Basin is believed to be the most important ground-water area in the Upper Colorado River basin. It is the principal area of ground-water inflow to the mainstem canyons in Utah, and is probably the largest contributor of ground water in the entire basin. It is also an area of large evapo-transpiration losses. The water so lost obviously does not contribute to the flow of the river at Lee Ferry; any beneficial use that can be made of it is therefore not chargeable against the state's quota of upper basin water supplies.

Studies are needed to determine the quantity stored in the ground-water reservoir of the Uinta Basin, the sources and amounts of annual replenishment, and the quantity and quality of water discharged from that reservoir. These studies are not directly related to the storage project, but are important in the development and utilization of water in an area which will be dependent in part upon that storage.

Classification of Federal lands for water development.--The Geological Survey is responsible for classification of Federal lands as to their water-storage and water-power values. These values are dependent in part upon the upper basin's ability to furnish water to the lower basin as required by compact, and dependent therefore upon the Colorado River storage project. Many of the streams in the basin are not adequately mapped, and geologic investigations of possible damsites must precede any classification as to their water-power or water-storage value. The topographic maps resulting from this program will be used in the classification of the public lands for power or

reservoir purposes. Topographic surveys along the rivers only will be made in areas not covered by the quandrangle mapping.

Additional geologic mapping.--As a result of the gathering of general geologic data, studies will be made of areas which may contain valuable mineral resources including metals, non metals and fuels (both solid and liquid). These studies may be needed in some places to determine that valuable mineral resources are not made inaccessible by flooding and to plan water and hydroelectric developments so that water and power will be available where needed for the mineral industries.

As these studies cannot be planned in advance of the general geologic mapping program additional funds will be needed to support them as the general program develops, and the need becomes apparent.

Many other activities listed in the following table are also part of a continuing program, which will extend beyond the three year period indicated in the following tabulation.

Estimated cost of basic-data program of Geological Survey
Colorado River Storage project and dependent projects

Program	1st year	2nd year	3rd year
Operation of compact gaging stations:			
Installation of 16 new stations	56,000	-	-
Rehabilitation of existing stations	45,000	20,000	-
Operation of 96 gaging stations	86,000	87,000	86,000
Analysis of dissolved and suspended load	63,000	63,000	63,000
Other stream gaging:			
Installation of 125 new stations	188,000	125,000	-
Operation of about 340 stations	240,000	270,000	270,000

GEOLOGICAL SURVEY

Program	1st year	2nd year	3rd year
Special erosion and sedimentation studies:			
Topographic mapping 1600 sq. mi.	$120,000	$150,000	$110,000
General geologic mapping	20,000	57,000	82,000
Hydrologic studies	20,000	12,000	12,000
Sediment-gaging	35,000	27,000	27,000
Dissolved load analysis	6,000	6,000	6,000
Special water-loss studies:			
Browns Park	50,000	40,000	40,000
Shiprock and/or Glen Canyon	50,000	40,000	40,000
Five reservoirs in the Green River basin:			
Topographic mapping 2200 sq. mi. (700 sq. mi. at Echo Park in progress)	165,000	210,000	150,000
Geologic mapping 2200 sq. mi.	34,000	76,000	82,000
Ground-water hydrology of about 1300 sq. mi.	6,000	14,000	18,000
Glen Canyon reservoir and vicinity:			
Topographic mapping 2600 sq. mi.	195,000	250,000	180,000
Geologic mapping 1700 sq. mi.	41,000	84,000	89,000
Ground-water hydrology	10,000	30,000	20,000
Water quality in Cataract Canyon	5,000	5,000	5,000
Navajo reservoir and vicinity:			
Topographic mapping 600 sq. mi.	45,000	55,000	40,000
Geologic mapping 600 sq. mi.	23,000	38,000	42,000
Ground-water hydrology	10,000	15,000	15,000
Reservoirs in Gunnison River Basin:			
Topographic mapping 1100 sq. mi. (470 sq. mi. in progress)	80,000	105,000	75,000
Geologic mapping 1100 sq. mi.	31,000	55,000	62,000
Ground-water hydrology	10,000	15,000	10,000
Ground water in Uinta Basin:			
Topographic mapping	150,000	190,000	140,000
Ground water studies	25,000	15,000	15,000

GEOLOGICAL SURVEY

Program	1st year	2nd year	3rd year
Classification of Federal lands:			
Tributary river surveys	100,000	300,000	300,000
Geologic investigations		100,000	100,000

Basic data requirements for general basin development

The Upper Colorado River basin is rich in natural resources whose development is not necessarily an integral part of the Colorado River storage project, although unquestionably the developments are likely to be related. Mineral resource development may be contingent upon the water or hydroelectric power made available by the storage project. Conversely the nation's need for certain minerals (especially those of strategic and critical importance) may be so urgent as to give marked impetus to the completion of certain phases of the Colorado River storage project.

With respect to topographic mapping, the need for early completion of mapping of the entire nation is generally recognized and has been approved in principle by the nation's leaders. It has been proposed that the national topographic mapping program be expedited and brought to completion within 20 years. If the national program is so expedited by appropriations sufficient to provide the necessary facilities, the mapping of the entire basin of the Upper Colorado would be completed within that time.

Under the national program for geologic mapping, most if not all of the Upper Colorado River basin will be mapped within 30 years. The mineral resources of the region include especially the mineral fuels (coal, petroleum, natural gas, and oil shale), base metals (copper, lead, and zinc), ferro alloys (tungsten, molybdenum, vanadium, manganese) and uranium, plus several other metallic and non-metallic minerals. In the national program priority is given to the areas most promising for the development of these resources.

Most of the water resources of the basin are intimately related to the Colorado River storage project. However, large areas are remote from the major streams and from the water facilities that will result from the storage project. In some of these areas ground water may be available for development. Very few important aquifers are known in the upper basin, and there are few wells of moderate to large yield. However, there is practically no detailed information as to the occurrence of ground water throughout the basin. A program of progressive appraisal of all ground water resources is an essential part of the general basic-data

program for the Upper Colorado River basin. The program should include investigations of sites for stock wells on public lands, in order to extend grazing into areas that are not now accessible to stock.

Estimated cost of general basic-data program
of the Geological Survey in the
Colorado River basin

Program	1st year	2nd year	3rd year
Topographic mapping	$1,500,000(a)	$1,750,000(a)	$1,750,000(a)
Mineral deposits	258,000(a)	405,000(a)	628,000(a)
Fuels	432,000(a)	1,285,000(a)	1,583,000(a)
Ground water	75,000(a)	75,000(a)	75,000(a)
Classification of Federal lands	50,000	100,000	100,000
Supervision of mineral recovery on Federal lands	c	c	c

(a) Part of comprehensive national program. Also these figures are for the entire basin.

(b) Upper Colorado River basin only.

(c) Dependent on private activity; income from leases is far greater than the cost of supervisory program.

NATIONAL PARK SERVICE

The functions of the National Park Service are an integral part of a program of land use of the Department of the Interior. The primary function of the Service is the administration of the National Park and Monument system. The Service seeks to preserve and render available to the public outstanding scenic, scientific, historic, and prehistoric areas of national importance. The "Park, Parkway and Recreational-Area Study Act" of June 23, 1936 authorized and directed the Secretary of the Interior ..." to cause the National Park Service to make a comprehensive study, other than on lands under the jurisdiction of the Department of Agriculture, of the public park, parkway and recreational area programs of the United States, and of the several states and political subdivisions thereof, and of the lands throughout the United States which are or may be chiefly valuable as such areas.... The said study shall be such as, in the judgment of the Secretary, will provide data helpful in developing a plan for coordinated and adequate public park, parkway and recreational area facilities for people of the United States."

With this responsibility and the fact that several areas of the National Park and Monument System would be directly affected by certain water-control possibilities being considered by the Bureau of Reclamation, it was determined that the National Park Service should investigate and furnish the Bureau with essential facts basic to the establishment of Departmental policy regarding the classification, development and administration of possible water-control projects and related areas in the basin, in which recreation is or will become an important dominant or collateral resource. On January 27, 1941, Secretary Ickes approved the proposal of the National Park Service and the Bureau for including a basin-wide recreational survey as part of the studies and investigations for the formulation of a comprehensive plan of utilization of waters of the entire Colorado River system.

The importance of recreational resources in the basin being recognized by the Bureau of Reclamation in planning for water conservation projects, the National Park Service, through a cooperative agreement with that agency, carried on a general survey of the recreational resources of the Colorado River Basin for the Bureau. The results of these investigations have now been published by the National Park Service in "A Survey of the Recreational Resources of the Colorado River Basin."1/

1/ United States Government Printing Office, Washington 1950. For sale by the Superintendent of Documents, Washington, D. C. Price $3.25.

NATIONAL PARK SERVICE

Subsequent to the above general survey, cooperation between the National Park Service and the Bureau has continued under a program of River Basin Studies financed by funds transferred by the Bureau and later by funds appropriated by the Congress for the purpose. Under the program it has been possible to make additional recreational studies of many of the water conservation projects being actively considered by the Bureau for development. This has included many important units in the Upper Colorado River Basin. Some of these units have now been authorized, and it is anticipated that National Park Service cooperation will include planning of recreational developments to the extent deemed appropriate in each case. Continuation of this inter-bureau cooperation in the field of recreational resources and their development is now covered by a Memorandum of Agreement between the Bureau of Reclamation and the National Park Service approved by the Secretary of the Interior on July 28, 1950.

Departmental policy is to retain control over and, through the National Park Service, develop and manage the recreational resources of those reservoirs of Bureau of Reclamation projects with recreational potentials of such magnitude that they are determined to be of national interest; and through agreements on long-term lease or by outright transfer of title to lands, provide for the management, by state or other appropriate local agencies, of the recreational resources on reservoirs of less than national importance following initial development with Federal funds. There is need for appropriate legislation to effectuate this policy, as well as authorization to allocate to recreational benefits a portion of the costs of water control projects. Legislation is also needed to authorize acquisition of lands essential to the recreational development and use of the resources in addition to lands acquired for the primary purposes of the project.

Where reservoirs are within or adjacent to national forests, an agreement has been effected whereby the subsequent administration, operation and maintenance of recreational developments will be assumed by the U. S. Forest Service as part of the National Forest recreational program.

It is a function of the National Park Service, to the extent of available resources, to conduct surveys and salvage of archeological remains endangered by water conservation projects. Cooperation of the Smithsonian Institution and state universities and other local organizations is also enlisted. As yet, comparatively little work of this nature has been done in the Upper Colorado River Basin.

Appropriations available to the National Park Service have been insufficient for the Service's functions in water resources development to keep pace with the progress of primary agency investigations, planning and development.

Basic data relating to recreational needs generally would be of great value in appraising recreational benefits and preparing well-considered, cooridinated development programs for water control projects. The preparation of reports by the National Park Service under the authority of the Park, Parkway and Recreational-Area Study Act terminated shortly before World War II and the reports prepared prior to that time are now largely out-of-date.

Evaluation of Recreational Benefits of Reservoirs

Under the terms of the inter-Bureau agreement approved July 28, 1950, it is the responsibility of the National Park Service to prepare for the Bureau monetary evaluations of potential recreational benefits. These monetary benefits may be used by the Bureau in computing the share of the joint costs of reservoir projects allocable to recreation and in justifying Bureau of Reclamation requests for funds for both specific and joint costs allocable to recreation, when such procedure shall be authorized.

The evaluations are based on analysis of all factors involved in the suitability of an area for recreational uses, type and probable extent of use, and developments and facilities which will be appropriate and adequate to accommodate such use. Basically, and provided no loss or destruction of existing recreational values is involved, it is held that benefits arising specifically from development of recreational facilities will be equivalent to total annual costs, capitalized over the anticipated useful life of the project. Similarly it is estimated that additional benefits accruing from joint use of a reservoir, for recreational purposes, will be equal to those arising from the development of facilities. The sum of these figures represents the total estimated monetary recreational benefits.

This amount, then, represents the judgment of the National Park Service as to a reasonable and conservative valuation of the recreational benefits accruing to the public as a result of a reservoir. It is necessarily conjectural, as the appraisal deals with many intangibles that are difficult to evaluate and involves an attempt to foresee conditions that may or may not materialize.

Upper Colorado River Basin Water Utilization Program and its Effect on Recreation

The report, "A Survey of the Recreational Resources of the Colorado River Basin," emphasizes the magnitude of outstanding scenic, scientific and other geographic and historical features of the basin.

From Gannet Peak in the Wind River Mountains, highest point in Wyoming, elevation 13,785 above sea level, Milner Pass in Rocky Mountain National Park, and the 14,000-foot mountain peaks in southwest Colorado to the 3,100 foot elevation of the river at Lee Ferry, marking the lower

end of the upper basin, lies a great region of forests, deserts, plains, mountains, canyons, and plateaus. In common with the whole basin, the Upper Colorado Basin is one of the most outstanding recreational sections of the United States, because of great variety of natural scenery, climatic conditions and areas and objects of scientific interest, its early romantic history, archeological background and present Indian and Anglo cultures.

In this nationally significant recreational region the entire gamut of outdoor recreational activities may be enjoyed, including hunting, fishing, photography, nature study, snow sports, boating, swimming, horseback riding, camping, mountain climbing and exploration. Two national parks, in wholeor in part, and nine national monuments have been established within the basin to preserve some of the most outstanding natural, scientific, and cultural features. Large sections have been included in national forests, wildlife refuges, wilderness areas, grazing districts, and to some extent, Indian reservations. Much of the basin is in public ownership, a natural corollary of a small and thinly scattered population.

It is only natural in a region so endowed that recreation should become one of the major industries. Agriculture is restricted largely to irrigated sections. Mining, lumbering, and the raising of cattle and sheep first attracted settlers to the basin, but the recreational features are now attracting many more; and as the various sections of the basin become better known and more accessible to the densely populated regions of the United States through improved highways and air transportation, catering to the recreational business should become a major industry. To foster this industry, it must be recognized that recreational use of land may in certain places be the highest or best use for the general welfare of the people in the basin and in great sections of the basin should be on an equal basis with other uses, such as grazing or production of timber. One of the most important recreational aspects of the basin is the great stretches of open range, unobstructed by buildings, fences, transmission lines, and other signs of modern civilization. As other sections of the United States become more and more highly developed, this one feature of the Colorado River country, if preserved, will have unusual appeal. Such preservation, at least in large measure, should not be difficult in the vast and wild region traversed by the Colorado River in the lower reaches of the Upper Basin. Here in dramatic contrast to the great forested mountain ranges along the Continental Divide where headwaters of the Colorado and the Green rise is desert and semi-arid country slashed by deep and colorful gorges and canyons.

In the development of water resources which are so vital to the basin, recreational use should be considered along with other uses, such as irrigation, power, municipal and industrial water supply. In the mountains and high plateau sections of the basin the clear, cold streams and lakes offer excellent fishing amid delightful surroundings. In some instances the recreational value of these streams and lakes may be such

as to make this their most important use. The Green River Lakes, New Fork, Willow, Fremont, Half Moon and Burnt lakes, within Bridger National Forest, along the slopes of the Wind River Range are natural lakes which are held to be unmistakably in this category. On the other hand, the original scenic values of Boulder Lake in the same area have been impaired by developments and would not be seriously affected by further utilization. The western slopes of the range in which these lakes are located include a mountain area of such exceptional scenic quality and recreational value as to be clearly of national importance.

In other sections, the creation of reservoirs for irrigation, important hold-over functions for compact obligations, or power will frequently create new water areas of recreational importance. There are instances where the raising of water in impoundments would submerge natural areas of recreational, scenic, and scientific value or archeological importance. In such cases, it must be decided whether a reservoir in the location justifies the sacrifice of these existing values.

In cases where important archeological features would be inundated by the reservoirs, there should be a thorough survey and excavation for recovery of artifacts and data, so that knowledge of the archeological material will not be lost forever. In the larger reservoir areas, surveys should also be made of flora and fauna and records kept of the original biota.

In varying degrees the recreational potentialities of many of the proposed Upper Colorado River Basin reservoirs have been studied by the National Park Service. These include, notably, the units included in the Colorado River Storage Project and reservoir units of the proposed "participating projects." Some reservoirs outside this group have also been surveyed and initial reports prepared on the findings for the Bureau. As project plans are further developed and construction is authorized, more comprehensive and detailed studies will be required in order to assure properly coordinated recreational developments that are commensurate with established needs, and in the general public interest.

As other projects in the basin are brought into the picture, additional investigations will be necessary. In this category are many possible units under various degrees of consideration in the Yampa, Upper Colorado, Gunnison, Dolores, San Juan and other tributary drainages. Some of these will involve diversion of water from the Colorado basin.

The adverse effects certain reservoir units of the Colorado River Storage Project would have on areas of the National Park System has been a matter of the gravest concern to the Service. The Glen Canyon Reservoir could impair the scenic value and even the stability of the Rainbow Bridge, the largest and most beautiful of all known natural bridges. However, it appears that measures to protect this national monument could and would be included as appropriate features of project development.

NATIONAL PARK SERVICE

The Curecanti and Crystal reservoir units of the project would regulate river flows through the Black Canyon of the Gunnison National Monument. While such river regulation involves changes in natural conditions that are held to be very undesirable, nevertheless it is recognized that the effects of flow regulation would not be sufficiently adverse to override the economic advantage to be gained thereby in the public interest.

Of the greatest concern to the National Park Service has been the inclusion in project plans of two reservoirs on the Green and Yampa Rivers within Dinosaur National Monument, where nationally significant scenic, scientific and other recreational values would be irreparably damaged or lost altogether by dam construction, related works and by inundation. However, after carefully weighing all factors and values involved, it has been determined by the Secretary of the Interior that the conservation and multiple use of these waters is more in the interest of the people of the West and of the whole nation than the preservation of existing values.

The foregoing problems are more fully covered in the National Park Service reconnaissance report dated November 1950 on the recreational values of the Colorado River Storage Project. The purpose of that report was to consider, in only a very broad and preliminary manner, possible recreational aspects of the project reservoirs, with due regard to existing conservation and recreational values. The scope of the report, based on the limited reservoir data and operational information currently available, in most cases, does not permit of analysis of economic factors involved, including consideration of possible recreational benefits or values on a monetary basis. It is contemplated that more detailed studies on certain of the project reservoirs and others similarly involved in the Upper Colorado River Basin water utilization and control plan will follow, in line with schedules of studies and developments.

In the event that any of the project reservoirs are to be created, the report recommends that arrangements be made for adequate archeological surveys, and, so far as judged necessary, for excavations and salvage of scientific artifacts and information.

It further recommends:

That the recreational resources inherent in the reservoirs receive consideration commensurate with their importance during all stages of project planning and development.

Land acquisition programs receive careful consideration where areas suitable and necessary for recreational uses and development are involved, whether by purchase or by arrangements with Federal agencies where applicable.

Arrangements be made to assure, in each case, adequate administration, operation and maintenance of recreational developments by some qualified agency prior to final planning and provision of developments with Federal funds.

Excerpts from the report concerning the ten reservoir units of the Colorado River Storage Project are given in the following sections.

GLEN CANYON RESERVOIR

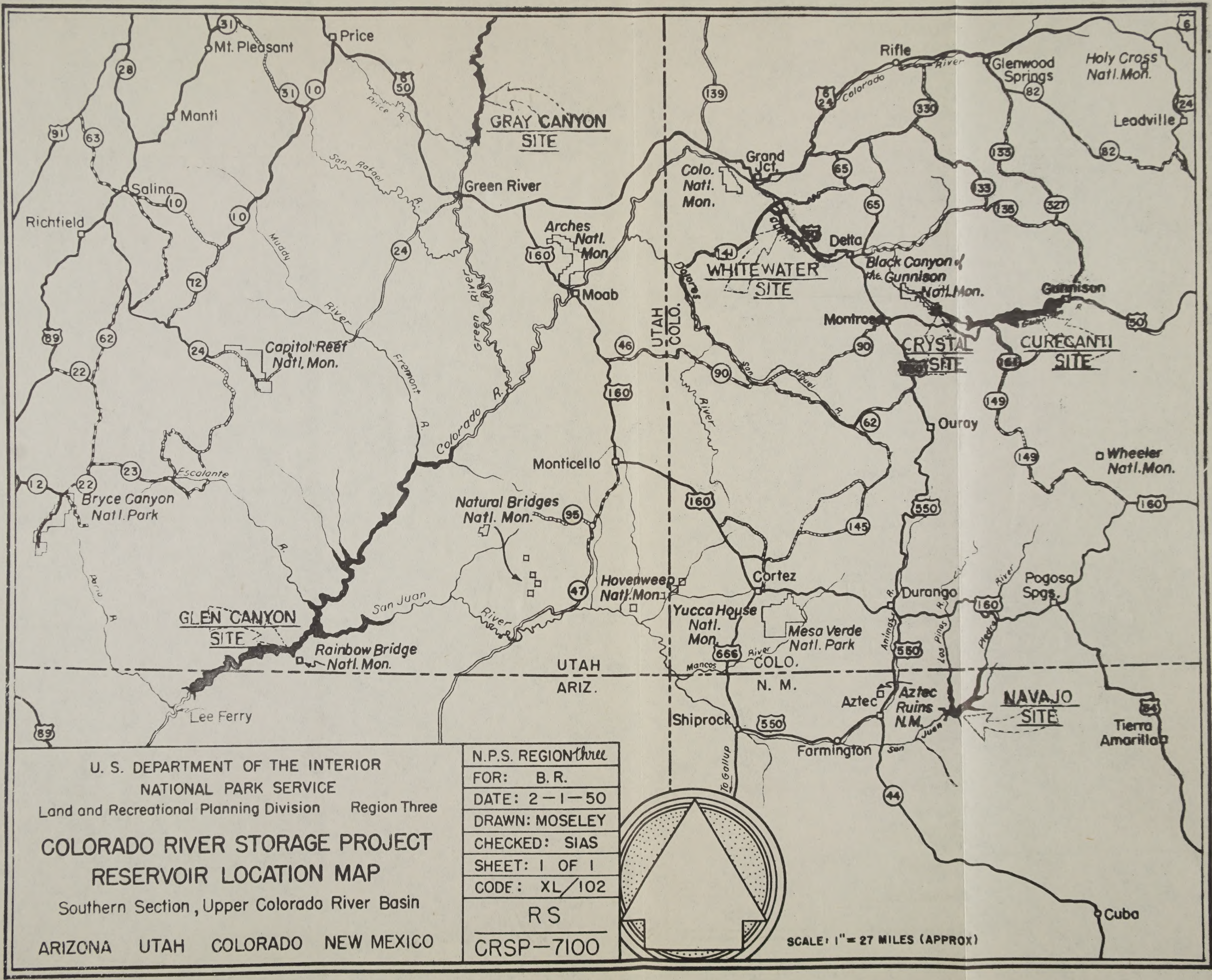
The site now under consideration for the Glen Canyon Dam is located near river mile 15 (i.e., above Lees Ferry, Arizona) in the Glen Canyon Section of the main Colorado River. According to information furnished by the sponsor, it would be possible to construct a dam at this site to impound 34,000,000 acre-feet of water which would correspond to a maximum surface elevation of 3,750 feet MSL. While the desired capacity has not been determined, physical data for a tentative capacity of 26,000,000 acre-feet have been furnished by the sponsor for use pending the completion of the present studies. These are given below:

Planned capacity	26,000,000 acre feet
Corresponding "dead storage" capacity	6,000,000 acre feet
Maximum water surface, el.	3,710
Minimum " " "	3,510
Maximum reservoir area	153,000 acres
Minimum " "	56,000 acres
Maximum reservoir length	186 miles to river mile 201
Minimum " " (approx.)	168 miles to river mile 183
Present river elevation	3,135 feet

Dam height, 580 feet above present river

The Glen Canyon Reservoir would offer the last opportunity for control of upper basin residual water flows for meeting compact deliveries to the lower basin at Lee Ferry. Provision for power production would be made. Regarding operation of the reservoir, the following information has been furnished:

> "Probable operation would pattern other main-stem reservoirs. During normal or above normal years of runoff, the reservoir drawdown would be less than thirty feet with storage used only for seasonal regulation of power releases. Extensive drawdown would result only during a protracted dry cycle with maximum drawdown the result of a cycle as severe as the 1931-1940 period. The reservoir would be refilled by storing the surplus flows of subsequent high years.


GRAY CANYON SITE
WHITEWATER SITE
CRYSTAL SITE
CURECANTI SITE
NAVAJO SITE
GLEN CANYON SITE
Price
Mt. Pleasant
Manti
Salina
Richfield
Green River
Grand Jct.
Colo. Natl. Mon.
Arches Natl. Mon.
Moab
Rifle
Glenwood Springs
Holy Cross Natl. Mon.
Leadville
Delta
Black Canyon of the Gunnison Natl. Mon.
Gunnison
Montrose
Ouray
Wheeler Natl. Mon.
Capitol Reef Natl. Mon.
Bryce Canyon Natl. Park
Escalante
Monticello
Natural Bridges Natl. Mon.
Hovenweep Natl. Mon.
Yucca House Natl. Mon.
Mesa Verde Natl. Park
Cortez
Durango
Pogosa Spgs.
Aztec
Aztec Ruins N.M.
Shiprock
Farmington
Tierra Amarilla
Cuba
Rainbow Bridge Natl. Mon.
Lee Ferry
UTAH
COLO.
ARIZ.
N. M.
Colorado River
Price R.
San Rafael R.
Muddy River
Fremont R.
Green River
Colorado R.
San Juan River
Dolores River
San Miguel R.
Gunnison R.
Animas R.
Los Pinos R.
Piedra River
Mancos River
Paria R.
To Gallup
SCALE: 1" = 27 MILES (APPROX)

U. S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Land and Recreational Planning Division   Region Three

COLORADO RIVER STORAGE PROJECT
RESERVOIR LOCATION MAP

Southern Section, Upper Colorado River Basin

ARIZONA   UTAH   COLORADO   NEW MEXICO

N.P.S. REGION three
FOR: B. R.
DATE: 2—1—50
DRAWN: MOSELEY
CHECKED: SIAS
SHEET: 1 OF 1
CODE: XL/102
RS
CRSP—7100

NATIONAL PARK SERVICE

Description of the Site

The narrow, vertical-walled, red sandstone gorge of the Colorado River at the 15-mile dam site is approximately 700 feet deep. Through a great deal of its length the reservoir will be similarly restricted with occasional extensive basins such as will occur at the state line where Wahweep and Warm Creek Canyons empty into the Colorado--the former a mile and a half above the dam site and the latter at the state line. Similar basin enlargements would occur shortly above the state line at the confluences of Cottonwood Canyon on the north and West Canyon Creek on the south. Between these creeks lies the historic "Crossing of the Fathers" area, which would be entirely inundated. A little more than 40 miles above the confluence with the San Juan River, where Bullfrog and Hall Creeks flow into the canyon from the north, another important reservoir enlargement would occur. More often, however, canyons and side draws drain into the river on comparatively steep gradients, and reservoir extensions into the draws would, for the most part, be limited. At elevation 3,710 the reservoir would apparently extend up the San Juan River 70 miles or more. The upper reaches of the reservoir would lie in the restricted confines of Cataract Canyon of the Colorado, nearly 20 miles above the mouth of Dark Canyon.

Glen Canyon Reservoir area lies in the heart of the so-called Escalante Country, or Canyon Lands, of southeast Utah, one of the most rugged, roadless and inaccessible regions of the United States. In the National Park Service survey of the recreational resources of the Colorado River Basin, this part of the basin is described as a "wild and fantastically eroded land of winding gorges and sandstone mesas whose vast expanses are punctuated at irregular intervals by the isolated, steeply upthrust masses of the Henry, Abajo, and Navajo Mountains. With the exception of the mountain summits, which are cool and moist, the greater portion of the area receives but little snowfall in winter and is characterized by a long, warm summer season. Average temperatures are higher than those of valleys to the north, in conformity with the decrease in latitude, but lower than those of deserts to the south. The annual precipitation ranges from about 6 to 14 inches with the greatest amount coming from thunderstorms during July and August. Into this desolate but spectacularly scenic sandstone area, through a deep, meandering gorge, flows the turbid San Juan River from the east, draining a far-reaching area, including La Plata Mountains, the San Juan Mountains and other lesser ranges on the Continental Divide, the Chuska Mountains, and enormous areas of mesaland in the interior of the basin. From the Wasatch and Aquarius Plateaus on the west come other but lesser, silt-laden streams, all carving the deep, winding canyons which have given this country its name."

Owing to very difficult access, and the extremely limited local population, probably numbering a hundred or less all told in the area,

present recreational use must be negligible, although the Fish and Wildlife Service reports that there are some catfish and Colorado white fish. The most notable recreational use of the area probably consists of the occasional "floats" or boat trips which are made down the river, notably down the San Juan and Colorado to Lees Ferry and sometimes beyond, even through the Grand Canyon to Lake Mead.

There is ample evidence that the reservoir area is rich in archeological material, as yet very incompletely surveyed. A reconnaissance of archeological sites in the Colorado River canyons between the Fremont River and Lees Ferry was made by boat in 1932. This covered in large part the main reaches of the river that would be flooded by the Glen Canyon Reservoir. The survey was made by Dr. Julian Steward, then of the University of Utah (later staff member, Bureau of American Ethnology, Smithsonian Institution, and presently on the faculty of Columbia University). Some 27 sites were located on the sides of the main canyon. It is probable that many other sites occur in side canyons often, however, above reaches that will be inundated by the reservoir. No known archeological remains presently within a National Park Service area are involved.

No study of historical values associated with this reservoir area has been made in connection with the report but what is probably the most interesting feature in this respect, namely, the Crossing of the Fathers, has been mentioned.

Effect of Glen Canyon Reservoir on National Park Service Areas

1. Rainbow Bridge National Monument

This choice, unique and highly significant National Monument is located in Rainbow Bridge Canyon shortly above its confluence with Aztec Creek which in turn drains into the Colorado River a little above river mile 68, or approximately 53 river miles above the dam. It comprises one quarter section or 160 acres. From U.S.G.S. topographic maps, it is estimated that the Rainbow Bridge National Monument is approximately four canyon miles from the main river. Grade surveys made by the Bureau of Reclamation indicate a canyon elevation of approximately 3570 at the west monument boundary and that the bottom of the canyon under the Bridge is at el. 3654.10.

The maximum water elevation now proposed would, at the site of the Bridge, rise approximately 56 feet within the restricted channel, would not overflow the channel and would be more than 11 feet below the lower of the two abutments.

Frequency data have not been provided. There is, therefore, no indication as to how often the contemplated maximum elevation would be reached or how long retained. Both factors have a direct bearing on the effects of the proposed reservoir on the Bridge.

Water backing up Rainbow Bridge Creek under the Rainbow Bridge would leave unsightly deposits of flotsam, as well as staining the walls of the gorge. However, by far the most serious effect of flood waters reaching the bottom of the water course beneath the span would be the danger of undermining the buttresses of the Bridge itself. Standing water would dissolve cementing materials in the rock causing the sides of the banks to slough off, thus rapidly narrowing the supports beneath the ends of the Bridge. It is conceivable that with water backing up no farther than to cause standing water in the water course beneath the Bridge, softening and sloughing of the banks of the water course could be, in a relatively few years, sufficient to cause the weakening of the ledges beneath the ends of the Bridge and the collapse of the Bridge itself.

The Rainbow Bridge is considered by some to be the world's greatest known natural bridge. Certainly it is an outstanding and world famous natural feature, with the protection and preservation of which the National Park Service is entrusted. It is held that no potential recreational values which could otherwise be determined to be inherent in the reservoir could compensate for the loss of this irreplacable natural feature to the public for all time to come. The National Park Service would be opposed to the Glen Canyon Reservoir on any basis or plan of operation which threatened the stability or natural scenic value of this national monument.

Analysis of the conditions attending the relation of Rainbow Bridge National Monument to the proposed Glen Canyon Reservoir, so far as they can at this time be determined, indicates that some modification of the reservoir and its operational plan might be possible, to an extent which would eliminate dangers of any adverse effect on the Monument without jeopardizing unduly the value of the reservoir for primary purposes. A reduction in maximum water level from the proposed 3710 feet to 3650 would accomplish this end.

The National Park Service is not, of course, in a position to express a valid opinion as to how seriously such a change in plan would curtail the value of the reservoir for primary purposes. It is, nevertheless, recalled that at one time a tentative spillway level at 3528 feet was considered in connection with the alternate "4 mile" site shortly above Lees Ferry. It is broadly estimated from area capacity curves furnished by the sponsor that lowering the maximum surface 60 feet would mean a sacrifice of storage capacity of between 8 and 9 million acre-feet. To what extent compensating increases in storage in other reservoirs above Glen Canyon could be accommodated has not as yet, apparently, been determined. These are possibilities which should be fully explored in advancing studies for the Colorado River Storage project.

Another method of protecting monument values is under active consideration. This would involve a cutoff dam in the canyon below the monument,

which, with appurtenant works, including a by-pass pumping plant, would protect the monument with completely negligible loss of Glen Canyon Reservoir storage capacity.

The sponsor has given assurance that adequate protective measures will be included in plans for project development.

2. Grand Canyon National Park and National Monument

This outstanding National Park (with the Monument) has been mentioned as an area which could be affected by a reservoir above a Glen Canyon Dam. To the extent this would be true would involve almost any plan of reservoir operation. The tributary San Juan River is a heavy silt bearer, and the creation of a river barrier below the mouth of that river would materially reduce the silt content of the Colorado River through the Grand Canyon. Scientifically, this is an important element in the over-all Grand Canyon National Park picture. However, since there are considerable contributions to Colorado River silt below the San Juan, changes in the appearance of the river could, possibly, be comparatively slight.

Conceivably of greater significance would be regulation of stream flows through the park, which now vary from minimum flows to the great rushing torrents which result from the melting snows in the high Rocky Mountain sources of the river.

It is not possible to determine exactly, at this time, how extensive effects on Grand Canyon National Park would be. However, on the basis of maintaining the natural conditions of National Park Service areas, any alteration of silt content or stream flow could be considered as an adverse effect.

Nevertheless, certain other elements in the possible effects of the Glen Canyon Reservoir on Grand Canyon National Park (and its related Monument) are noted. These involve the probable reduced fluctuations in the proposed Bridge Canyon Reservoir, presently under serious consideration on the Colorado River below Grand Canyon National Park. Reduction in fluctuations in the Bridge Canyon Reservoir would be most apparent in the upper reaches, where both Grand Canyon National Park and Grand Canyon National Monument would be directly involved. In the latter connection, too, reduction in silt and river debris which would occur as a result of the Glen Canyon dam would likewise reduce the unsightly effects of fluctuation in the lower reservoir.

Potential Recreational Use

In the event that it is possible to realize a Glen Canyon Reservoir which would not jeopardize irreplaceable natural values in Rainbow Bridge National Monument, rather striking advantages could result from the creation of an extensive reservoir in this scenic area.

NATIONAL PARK SERVICE

In the National Park Service section of the Interim Report on "The Colorado River" (July 1947) it was noted that "much of the country bordering the Colorado and Green Rivers through this section of Utah is of high recreational value. It is a region of great colorful spaces, mountains, plateaus, canyons, desert, forest and weird formations, probably the greatest display of erosional effects in the United States, other than the Grand Canyon, and equally grand, though different in character."

Such a reservoir could warrant developments commensurate with estimated recreational use. High among potential values would be the advantages of waterborne access to remote corners of this wild canyon country, including the vicinity of the Rainbow Bridge National Monument. At present, difficulty of access to this natural wonder has limited public enjoyment to the hardy and privileged few who can afford the time, cost and effort of reaching it over a pack trail.

The character of Glen Canyon at the dam site would make access to the reservoir difficult, although the general area would be reached over project construction roads. The situation would be somewhat similar to that at Hoover Dam and Lake Mead, where actual access to the reservoir for general recreational purposes is not in the gorge at the dam, but at various points above the dam where short areas are suitable for access and related developments. At this reservoir the great bay formed where Wahweep and Warm Creek valleys enter the Colorado could function in this way. Construction of roads into this area from the dam site would be rather difficult and costly, but, it is believed, not prohibitive. There are indications that it would also be possible to reach this area by road from Kanab, Utah.

It may be feasible to approach the reservoir at some point on the west side near the base of the Kaiparowitz Plateau, and again in the vicinity of Hite, where possibilities of constructing a main highway bridge across the river shortly below the mouth of Fremont (Dirty Devil) River are under consideration. Such a bridge would service an important thoroughfare across the wild country of southeast Utah. The nature of this area indicates that this through road approximately midway between present highway crossings at Moab, Utah, and near Lee Ferry, Arizona, would very probably be the only trans-Escalante Country highway for many years to come. It could afford interesting access to the upper reaches of a Glen Canyon Reservoir.

A more comprehensive study of recreational possibilities which may be inherent in the Glen Canyon Reservoir may be undertaken shortly. Consideration of potential recreational use can be more appropriately discussed in such a report than in this preliminary review of the Colorado River Storage Project as a whole. In general, however, it has been noted in earlier comments on the proposed Glen Canyon Reservoir that the Wahweep and Warm Creeks area appears to be a logical and desirable place for

recreational boating and housing facilities, and for headquarters for boating operations and parties wishing to explore this section of Glen Canyon by land or water.

It is emphasized that earlier studies of this project were based on plans of reservoir operation which could not involve such irreplaceable natural values as those which current plans could critically jeopardize at Rainbow Bridge National Monument.

Recommendations

The primary recommendation concerns adequate protection of the nationally significant values in Rainbow Bridge National Monument.

It is especially important that arrangements should be made to fully explore archeological sites in the Glen Canyon Reservoir area and to effect salvage operations so far as justified to prevent loss of artifacts and scientific information.

WHITEWATER RESERVOIR

The Whitewater Dam site of the Whitewater unit is on the Gunnison River shortly above the confluence with the main Colorado River, in west central Colorado. It is about two miles south of the small town of Whitewater (on U. S. Highway 50), and 9-1/2 miles southeast of Grand Junction, most important center of population in this part of Colorado.

The following information has been provided regarding the operation of the reservoir:

> "The Whitewater unit of the Colorado River Storage Project has several potential purposes, some of which are dependent upon decisions which have not been made at this time. For the purpose of present studies, the best estimate is that the reservoir will furnish replacement water (51,400 a.f.) to Orchard Mesa Lands, presently served from the Colorado River. The remaining capacity will be used for regulation for the generation of firm energy. Actually by operating the reservoir as described above, the reservoir can be credited with providing considerable holdover storage for delivery to the lower Colorado River Basin during periods of low runoff.
>
> "The above method of operation will be altered when additional storage is provided upstream on the Gunnison River or if future depletions on the Upper Colorado River and its tributaries make replacements to the Grand Valley Canals necessary."

Analysis of the chart showing monthly reservoir stages through period of operation (1921-1940 inclusive) and the related table giving pool surface elevations at the end of each month for the same period (both furnished by the sponsor) reveals that operation of the reservoir would be singularly favorable for recreational uses. In common with other impoundments in the main Colorado system, minimum pools would occur late in the winter or early spring--quite consistently about the end of March. With equal consistency, heavy flows from melting high mountain snows would fill the pool to normal capacity by the end of May. Fluctuations during the most important recreation-use seasons would tend to be very nominal, reservoir spills from overflows occurring generally during the summer months, and only by late summer and fall would the long gradual drawdown to late winter lows begin to be noticeable.

The Bureau of Reclamation has furnished the following pertinent information in connection with this reservoir, which is under consideration for irrigation, power, holdover and replacement for transmountain diversion:

Planned capacity	880,000 a.f.
Maximum water surface elevation	4,880
Minimum water surface elevation	4,756
Maximum water surface area	10,250 acres
Minimum water surface area	2,700 acres
Present stream bed el. at dam site	4,630
Length of reservoir at maximum	35 river miles
Length of reservoir at minimum (approx.)	18 river miles
Dam height	255 feet

At extreme high water, the reservoir would extend to a point 4 miles west of Delta.

Description of the site

Located entirely within the lower reaches of the Gunnison River, the reservoir basin lies in rather gently rolling, unspectacular valley lands which intervene between the massive, 10,000 feet high Grand Mesa on the northeast and the similarly forested height of the Uncompahgre Plateau on the southwest. Vegetation is generally sparse, involving some cottonwoods, sycamores, etc., along the river bottom and some juniper along semi-arid bordering ridges and hills. For the greater part of its length, the Bridgeport Reservoir would be confined to the rather restricted inner valley which has been eroded through the broader valley. The most notable escape from this narrow course would occur at the confluence with Kannah Creek shortly above the dam site. The lower Kannah Creek tributary drainage empties into the Gunnison through a narrow opening in the bordering ridge. Immediately above this narrow passage, which would assume the

character of a gut with the formation of the reservoir, would be a considerable bay surrounded by comparatively gentle slopes and rolling land which would, in two or three places, require dikes to prevent high water overflows into a secondary valley drainage which roughly parallels the main river and empties into it below the dam site.

The reservoir will be more or less directly accessible practically throughout its entire length from important U. S. 50 which parallels the river course within a few miles along the northeast side. This highway crosses Kannah Creek where some relocation is indicated. Minor roads, including some county roads, extend into and in some cases across the valley from the main highway, affording access to the farms and cultivated areas that occur in the fertile river bottom. One such road extends into the basin approximtely midway in the over-all reservoir, to farms at and near the old Denver and Rio Grande Western Railroad station of Broughton (an old line of the railroad traversing the river bottom throughout the length of the reservoir). A county road also crosses the valley at Escalante Creek well up the reservoir basin, above the minimum reservoir pool indicated at el. 4,756. Although U. S. 50 rather closely parallels the river, the topography is such with generally low, intervening ridges that views of the reservoir from the highway will be comparatively rare and restricted, other than at the Kannah Creek Bay. The prevailing impression on the reservoir would be one of greater remoteness than will actually be the case.

Although the scenery in the vicinity of the reservoir has little to recommend it in a state like Colorado, nevertheless distant views are impressive, in some cases spectacular. The former involve the dominating massives of the Grand and Uncompahgre Plateaus, while the latter include somewhat more distant views of the great Alpine uplifts of the main San Juan ranges to the south which will probably be seen even from the reservoir in the upper reaches of high pools, where bordering bills are reduced and more open valleys extend southward to Montrose and afford views of the towering mountains beyond. To the east lie the impressive West Elk and related outlying mountain ranges of the main Continental Divide Rockies.

The upper reaches of the Gunnison River, including the Black Canyon of the Gunnison National Monument, are spectacular and offer some of the best trout fishing in this part of the country. However, the Fish and Wildlife Service, in a preliminary report, has indicated that fish in the lower Gunnison River where the Bridgeport Reservoir would be located "consist primarily of catfish and Colorado white fish, with a few large-mouth black bass and many species of rough or forage fishes. Existing use is of minor importance." That agency also mentions Gambel quail habitat along the Colorado and Gunnison Rivers in the vicinity of Grand Junction and Delta, Colorado. It is believed that present recreational use of the reservoir site is largely, if not wholly, restricted to minor fishing and

some small game hunting. It does not appear that recreational values of any importance would be destroyed by the creation of the reservoir.

Very little is presently of record with the National Park Service regarding possible archeological or historic investigations in the Bridgeport Reservoir area. These matters should be sufficiently checked prior to project development to avoid losses of scientific artifacts and information.

No National Park Service area or interest, or any State park area will be affected by the Bridgeport Reservoir or its operation.

Potential recreational use

Even in the absence of immediate scenic values of note, this reservoir should assume appreciable significance for recreation. Plans of operation currently being considered are very favorable to such use. It seems probable that minimum pools would very rarely occur, that normal low pools would be in late winter and that fluctuations in relation to power pool operation (for firm power so far as possible) would tend to be nominal.

The reservoir would be long and winding, with somewhat varied shore lines. It should lend itself to a considerable variety of boating, being somewhat safer in this respect than larger, more open and exposed bodies of water.

In summing up their report, the Fish and Wildlife Service indicated that the Bridgeport Reservoir would be particularly desirable (but admittedly "not so much for any values created by it, but as an alternate site for the Ruedi Reservoir on Frying Pan River, which would cause major losses in irreplaceable fish and wildlife resources").

It is possible that during the warmest summer months there could be considerable appeal for swimming--a form of recreation unlikely to be in much demand, for instance, on the Grand Mesa and similar areas nine and ten thousand feet above sea level.

In appraising the potential recreational values and opportunities believed to be inherent in this considerable reservoir, due consideration should be given to the outstanding recreational appeals generally exercised in southwestern Colorado, many of which assume regional and even national importance. The high, cool, heavily forested areas on nearby Grand Mesa, with its many glaciated lakes is a typical example of such appeal. Nevertheless, there is reason to believe that such outstanding recreational areas can be complemented to an appreciable extent by the Bridgeport Reservoir, very largely because of its much lower altitude, being under 5,000 feet. The recreational season will be much longer at

the lower altitude, high mountain areas often remaining closed until late in the spring, and being similarly closed by early snows and cold in the autumn.

The relation of important U. S. 50 to the reservoir has been noted, this highway being one of the main, east-west routes through central Colorado between Colorado Springs and Pueblo to Grand Junction and on to Salt Lake City.

While some recreational use of the reservoir could be derived from travelers along this route, a great deal in this respect would depend on the scope and character of facilities provided for the public, notably in the way of accommodations. Also, the bulk of summer tourist travel over this, as well as other routes through Colorado, will continue to have the pick of higher, cooler and far more scenic areas (often including lakes or reservoirs) in this spectacular state than could ever be associated with this reservoir, regardless of developments. It is, therefore, believed that the bulk of recreational use made of the reservoir will be derived from visitors from local communities such as Montrose, Delta, and notably Grand Junction with related communities in that important section of the Colorado River Valley.

It is concluded that the recreational significance of the reservoir, while considerable, would nevertheless be primarily local.

Possible recreational development sites occur on the reservoir, notably in relation to the Kannah Creek Bay area, directly accessible from U. S. 50. Here, too, shore areas will be fairly gentle and topography well suited for a general recreational development area, with provision for boating, swimming, picnicking, camp grounds, possibly a lodge and appurtenances. As elsewhere on this reservoir, considerable tree planting will be required to assure the full appeal inherent in the site.

Other areas which can be considered as suitable for potential developments would occur near Broughton and near the present Escalante road crossing--but the latter depending on frequency of drawdowns that might leave the area above accessible water. Apparently only once would this condition have occurred during the period of study, and then only for late spring months,

The preliminary right-of-way map furnished by the sponsor indicates that most of the privately owned land in the main river bottom will be acquired by purchase. In large measure, these private holdings appear to be flanked by public domain which should reduce land acquisition problems, for well considered recreational developments, to one of suitable agreement with the public agency involved. It is quite possible, however,

that in large measure lands around the Kannah Creek area are in private ownership and considerable care will be necessary to assure acquisition suitable and adequate for all phases of reservoir operation and utilization, including recreation.

Recreational facilities planned for the reservoir should be considered primarily for the largely local day-use that can be anticipated, with allowance for concessioner enterprises, including possible accommodations for the traveling public on U. S. 50.

GRAY CANYON RESERVOIR

The Gray Canyon Reservoir dam site is on the Green River, Utah, 22 River miles above Green River and some four miles above the confluence with the Price River. It is between Grand and Emery Counties. The site is in the steep-sided, sometimes precipitous canyon which traverses the plateaus out of which the main Tavaputs Plateau rises shortly to the north and which drop abruptly into the valley below the dam area to form the Book Cliffs. The head of the reservoir, 53 river miles above the dam, will be shortly below Minnie Maude Creek which drains the northerly slopes of West Tavaputs Plateau and 53 river miles below Ouray near confluences with the Duchesne River which drains east slopes of the Wasatch Mountains to the west and the south slopes of the Uintas on the north, and the White River on the east which heads in Colorado.

It has been indicated that the primary purpose of the reservoir would be for power, with winter drawdowns to maintain firm energy generation with rapid refilling in the following spring. It is possible the reservoir could have some value for sediment control, and an allocation of 641,000 a.f. is indicated for "holdover" storage in connection with this important phase of the Colorado River Storage Project. Recent studies, however, appear to emphasize the importance of power output, with as constant a maximum head as possible maintained for this purpose. On this basis, current information furnished by the sponsor is as follows:

> "Studies of the Gray Canyon Reservoir indicate that maximum energy generation can be expected if the reservoir is maintained at or near its maximum capacity of 2,000,000 acre feet. Prior to the need for extensive holdover demands (in 150 to 200 years based on present estimates of sediment encroachment into the system of reservoirs) on Gray Canyon Storage, the water surface fluctuations would be limited to a maximum drawdown of about 40 feet during the winter months with refilling expected each year by May or early June."

The following data have been furnished by the Bureau of Reclamation or estimated from related information similarly provided:

Planned capacity	2,000,000 a.c.
Maximum water surface elev. MSL	4,590
Minimum water surface elev. (approx.)	4,400
(based on inactive storage of 500,000 a.f.)	
Maximum water surface area	10,750 acres
Minimum water surface area (approx.)	5,200 acres
Length of reservoir, at maximum	53 miles
Length of reservoir at minimum, (approx.)	28 miles
Present stream bed el. at dam site	4,150
Height of dam	445 feet

Description of the site

The lower end of the reservoir, for approximately ten miles above the dam, traverses the steep barren gorge through the southerly outlying mesas of the Tavaputs Plateau. These "steps" range in elevation between 5,000 and 6,000 feet but are in turn dominated by the massives of the East and West Tavaputs uplifts ranging up to 9,000 feet and more and between which the Green River has cut its way through the Gray Canyon from which the reservoir takes its name. The rise to these higher plateaus is abrupt on the south, forming the Roan or Brown Cliffs which extend easterly into Colorado. Beyond Gray Canyon which appears, from the air at least, to be in effect more truly canyon-like in character than a gorge, the reservoir will continue through the narrow passages of the northerly outlying table lands and mesas of the central Tavaputs plateaus. These reaches of the river traverse so-called Desolation Canyon which appears to be appropriately descriptive of this barren, isolated section of the country.

From the limited map data available, it is estimated that throughout its length the reservoir will be almost entirely restricted to a narrow body of water. The 10,750 surface acres noted for the full pool of a 53-mile long reservoir strengthens this impression.

Vegetation ranges from scattered juniper and minor range vegetation on the lower steppes to pinion country on the higher plateau areas.

While definitely rugged in a desolate sense, in this generally highly scenic part of the country the Gray Canyon Reservoir site can by no means be characterized as noteworthy in this respect. Gray Canyon appears to be especially appropriately named. The rich colorings which occur in such variety and abundance in lower reaches of the Green and Colorado rivers through the Escalante Country to the south and on through

the Grand Canyon of the Colorado, are notably lacking here. Nor, from the reservoir itself, lost in narrow gorges and canyons, would there be the inspiring views of the Wasatch Mountains to the west, the Henry and distant Blue Mountains to the south, or the alpine peaks of La Sal Mountains to the southeast.

Access will have to be provided for dam construction purposes, but otherwise the reservoir area will be singularly inaccessible, except for the occasional ranch trails which may penetrate the barren lands of this part of Utah. Nor, in the foreseeable future, does it appear at all likely that this general inaccessibility is likely to be altered. Access to the dam area will be from U. S. 6-50, either at Green River or down the Price River from Woodside on the west.

Perhaps largely due to inaccessibility, coupled with the rugged and barren aspect of the country, it seems highly improbable that the proposed reservoir area can offer much, if anything, in the way of present recreational values. There may be some hunting in the area and, in the comparatively more accessible reaches of the river between the dam site and Green River, Utah, some fishing. These are values which, to the extent they occur, will undoubtedly be adequately considered by the U. S. Fish and Wildlife Service. It seems reasonable to assume that no recreational values of importance will be destroyed by the development of the Gray Canyon Reservoir.

National Park Service archeologists have no record of archeological investigations having been made in the barren reaches of the Green River which would be inundated. It is believed very unlikely that archeological sites which may occur would assume much, if any importance.

Potential recreational use

The reservoir operation plans, involving only nominal drawdowns during the winter, nonrecreational use season, and quite constant summer water levels could be indicative of conditions rather unusually favorable to recreational uses. However, the local population which could most readily be drawn to the reservoir is extremely small and scattered. The population of the town of Green River in 1940 was only 470, and there is little indication that it has changed much since the last census. The barren and uncolorful aspect of the reservoir area seems unlikely to attract tourists from U. S. 6-50, except to the extent of the minor detour necessary to see the dam itself, which, rising 445 feet above the river in the narrow gorge, could have some sightseeing appeal.

The reservoir would offer fine opportunities for boating on its own merits, and this form of recreation could be stimulated if fishing proves to be good. A fairly constant water level encourages the belief

that this could be the case, but this phase of reservoir utilization can best be appraised by the Fish and Wilflife Service. Recalling the rather remarkable trout fishing which has developed in the Colorado River from the cold water released through Hoover Dam, at a much lower altitude, it seems highly probable that a similar situation would be created below the Gray Canyon Dam where the Green River would be comparatively easy of access, at least in reaches below the canyon which opens through the Book Cliffs above the main highway.

No detailed recreational survey of the reservoir area has yet been made, but air reconnaissance leads to the belief that in short stretches along the extended shore line (well above a hundred miles) places would occur in side draws and bays, even in this rugged country, where boats could be beached for camping. Such recreational use of the reservoir as noted above will probably be very limited due to the very small local population which could be most directly served by the reservoir and general lack of scenic and other appeal for tourists traveling U. S. Highway 6-50. Probably only a widespread and justified reputation for exceptionally good fishing would be likely to materially alter this situation.

Consideration of possible recreational developments for the reservoir should be weighed in the light of the probably very limited use which can be anticipated. Some facilities can possibly be arranged by means of which boating could be handled, although undoubtedly considerable ingenuity would be necessary in this regard, especially if provision for this activity were to be made at or near the dam. This location would normally be the most accessible over construction roads and closest to centers of population and the main highway. But it will be seriously complicated by topography.

It is very unlikely that provision for overnight visitors would be warranted. Development of accommodations on a sound business basis will probably be stimulated at Green River both during dam construction and subsequently for tourists--especially if river fishing below the dam assumes importance. If construction access should be from Woodside via the Price River route, a similar impetus for accommodations would undoubtedly occur in that small community.

Recommendations

While the potential value of the Gray Canyon Reservoir for boating and related recreational activities appears to be substantial, the limited use that can reasonably be anticipated because of location, small local population, difficult access and lack of scenic appeal should be recognized. However, it is recommended that ways and means of accommodating boating activities receive careful and early consideration. This should be done at the time dam construction plans are in progress in an

effort to provide suitable reservoir access so far as possible to reduce subsequent difficulties and greater costs which might otherwise be involved.

NAVAJO RESERVOIR

Present plans call for locating the Navajo dam on the San Juan River shortly below the confluence with Pine River (Los Pinos). More generally the dam would be in northeastern San Juan County and northwestern Rio Arriba County where the San Juan River forms the boundary between these two counties in northwestern New Mexico. The Pine River arm of the reservoir will extend almost to the Colorado state line and the main San Juan will extend about 3 miles or so into Colorado at high water elevation.

The dam site is approximately 45 miles east of Farmington, New Mexico, and about 35 miles southeast from Aztec. Durango, Colorado, is 45 miles northwest of the San Juan arm of the reservoir and about 40 miles from the Pine River arm. The latter is not immediately accessible by road, but Bureau of Reclamation plans contemplate location of the construction road south from Ignacio, Colorado, which would provide direct access to the dam area and to points along the Pine River.

According to the preliminary plans advanced by the Bureau of Reclamation, the storage in the Navajo Reservoir would be used both for energy generation and holdover storage with the maximum elevation at 6,050.0 MSL and maximum drawdown to 6,010 except during years of extremely low runoff when it could become necessary, under the plan of ultimate development, to reduce water levels to dead storage elevation. It appears that operation could be compatible with general recreational use of the reservoir.

Total reservoir capacity	1,200,000 acre feet
Maximum water surface elevation	6,050
Minimum water surface elevation	6,010
Maximum water surface area	10,800 acres
Minimum water surface area (approx.)	6,800
Length of reservoir at maximum (approx.)	33 miles
Present stream bed elev. at dam site	5,725
Dam height	335 feet

According to the 8-year period of study provided by the sponsor, fluctuations will be nominal, with the reservoir at full pool by the end of May something like 5 years out of 8. The lowest elevation which would have been reached during the study period was 6,010, only 40 feet below full pool, and that would have occurred in late November. The recreational use season low would have been at el. 6,030, late in October. At no time during the 8-year fluctuation study would operation have seriously interferred with recreational use of the reservoir.

At maximum elevation of 6,050.0, the reservoir would extend approximately 30 miles up the San Juan River reaching widths of a quarter to one and a half miles. The Pine River arm would reach some 10 miles varying in width from one quarter to three quarters of a mile. The La Jara canyon would be inunddated for some 5 or 6 miles. There would also be other inlets and bays of smaller note but of considerable recreational interest for boating and fishing.

Description of the Site

Rising in Colorado, the San Juan River is the largest stream flowing into or through New Mexico. It flows through the northwest section of New Mexico for a distance of 100 miles. The surrounding topography in the vicinity of the reservoir is the characteristic mesa land with the San Juan River flowing often several hundred feet below the top mesas. Occasional lower benches intervene between the larger table lands and the river channel bringing available recreational use space within accessible reach of the proposed lake levels.

The flat mesas above the reservoir area are sparsely vegetated with scattered pinion and juniper. There is a notable lack of larger trees for shade. This lack could be altered, however, in the vicinity of recreational development sites by spotting cottonwoods or other shade trees when water becomes available.

The open character of the land permits wide panoramic views that hold considerable interest. However, in conforming to the usual open aspect of the New Mexico landscape, the scenic value surrounding the Navajo site fails to impress one with any individuality worthy of special consideration.

Archeologically, there is known to be much of significance in the San Juan River Basin. Although little or no search has been made in the area of the Navajo reservoir site, the Smithsonian Institution should be kept informed of the status of the project in order to allow ample time for proper investigation and clearance.

Potential recreational use

Existing recreational values along the San Juan River are very minor in the vicinity of the Navajo reservoir area. Such use appears to be limited almost exclusively to fishing on which there is no great value at present. In fact the U. S. Fish and Wildlife Service believes that actual fishery values could be increased by impoundment of the reservoir.

The opportunity for general recreational use will also be enhanced by the reservoir and could include boating, fishing, picnicking, and perhaps some camping. Swimming could become a minor function, but suitable space

for a beach appears, at present, only at the upper end of the reservoir and would not be sufficiently well related to population to draw day-use visitors for that purpose. The limiting factor to general development seems to be population. Not only is the immediate area rather sparsely populated, but there will be complications concerning fishing licenses for residents of Colorado who wish to fish in the New Mexico portion of the reservoir. To a lesser extent the reverse may also be true although the Colorado section of the reservoir will be quite small compared to the New Mexico portion. If a reciprocal license could be arranged to accommodate both New Mexico and Colorado fishermen, the recreational use potential of the reservoir would be considerably enhanced.

Comparing the relative areas of population influence in Colorado and New Mexico on a county basis discloses that San Juan (17,115) and Rio Arriba (25,352) counties in New Mexico had a combined population in 1940 of 42,467, whereas La Plata (15,494) and Archuleta (3,806) Counties in Colorado had combined population of only 29,300. Since many of the Colorado residents will be attracted to the Vallecito reservoir on the Pine River well above the tail waters of the Pine River arm of the Navajo reservoir, the potential drawing power from Colorado would be further reduced.

Appraising the expected recreational use at the Navajo reservoir on a strictly local basis, it is expected that most of the patronage will come from residents of New Mexico and more particularly from the area around Farmington (1940 population 2,161) and Aztec (1940 population 756) both of which have increased in population since that time. Because of recent oil and gas developments in the area, it is also probable that future population increases will considerably surpass those of the past decade. There is a local need for water-type recreation in this area, and it is anticipated that these local values appraised will be the probable extent of the recreational benefits resulting from the impoundment.

Recommendations

It is recommended that the Navajo Reservoir, as presently proposed by the Bureau of Reclamation, be considered for recreational development fundamentally for local use. Such development could include limited general development in the vicinity of the dam where it would be conveniently accessible via the construction road. Access from the Farmington and Aztec areas should be provided as directly as possible and might include justification for a road from the floor of the canyon to the top of the mesa area on the north side of the reservoir.

Depending upon the degree of success in arranging for a reciprocal fishing license for residents of Colorado to fish in the New Mexico part of the reservoir, it may become feasible to develop a recreational area at

the upper end of the reservoir near the Colorado state line. Suitable and well-related space is located on a low bench on the north side of the reservoir near the maximum water level just south of the state line. This bench extends northward across the line into Colorado so that if licensing arrangements do not result in a mutually satisfactory solution for residents of both states, it would be possible to develop a small area in Colorado from which direct access could attract quite a few visitors. While early consideration should be given to the development of the sites recommended, it does not seem feasible to recommend actual land acquisitions or specific development until later studies introduce more definite information on actual operation, definite location of the construction road, and the feasibility of arriving at an agreement for providing reciprocal fishing licenses.

Archeological investigation is an important factor in clearing the way for any impoundment in the San Juan Basin. Early clearance should be sought to allow ample time for excavation and removal of valuable material believed to exist in the area.

CURECANTI RESERVOIR

The Curecanti Reservoir will be impounded behind a high (475') dam at the Blue Mesa dam site on the Gunnison River in the upper reaches of the Black Canyon, shortly below the mouth of Lake Fork and three and a half miles below Sapinero. The whole reservoir area is in Gunnison County, Colorado. The dam site is some thirteen miles or more above the Black Canyon of the Gunnison National Monument.

Earlier studies made by the Bureau of Reclamation for impoundments at the Blue Mesa site involved a very much smaller reservoir. The present plan calls for an impoundment that will extend up the river nearly to the town of Gunnison an estimated overall distance of something like 30 miles. It is estimated from limited, small scale, U.S.G.S. topographic sheets available for this area that the large basin shortly above the gorge in which the dam would be located would be as much as a mile and a half to two miles in width.

Information furnished by the sponsor indicates that the primary purposes of the reservoir are for holdover storage in connection with the Colorado River Storage Project, of which it is one of the units, and for power production. Utilized for these functions, it appears that a high degree of river regulation would be achieved, 2,000,000 a.f. out of a total of 2,500,000 a.f. being indicated for holdover storage.

The following data have been furnished by the sponsor, or estimated from related available information:

Planned capacity	2,500,000 a.f.
Maximum water surface el.	7,635
Minimum water surface el. 500,000 a.f. inactive storage from water surface fluctuation chart	7,455
Maximum water surface area	18,200 acres
Minimum water surface area (estimated from area capacity curves at 500,000 a.f. inactive storage)	5,200 acres
Length of reservoir at Maximum	30 miles
Length of reservoir at inactive storage, est.	17 miles
Dam height	475 feet

The following statement regarding reservoir operation has been provided by the sponsor as follows:

> "Reservoir fluctuation will normally follow the drawdown pattern shown for the period 1927-1930. Somewhat greater drawdown will result in years of extremely low run-off such as 1931-1934. Under conditions of ultimate development, which is expected in about 75 years, it is anticipated that irrigation requirements during years of extreme drought might necessitate the evacuation of the reservoir to the dead storage level for short periods."

Subsequently more extended period of study data for the reservoir have been made available, involving a thirty-four year period, 1914-1947. From this extended table it is possible to make somewhat more sound deductions regarding future probabilities, especially since the period included the years of historically low flows beginning in the early thirties. According to about the first 20 years of the study period, which it is believed represents within close limits a normal cycle of run-off, the reservoir would be filled to capacity about five years out of thirty-four and would approach full pool within 5 feet on three other times.

Under ultimate flow conditions, only once during the 32-year period of study provided would the reservoir have filled to within 2 feet of maximum elevation, and frequently would fall far short of full pool. This indicates virtually complete river regulation.

Analysis of capacity tables in relation to area, capacity, elevation curves which have been provided by the sponsor, is summarized in the following table:

Curecanti Reservoir Water Elevations, Normal and Abnormal

Fluctuations With Present Modified Flows

a) Under Normal Cycle Conditions	
Maximum pool (full pool) el.	7,635
Minimum, end of Aug. approx. el.	7,545
Average, end of June (20 yrs.) el.	7,608
Average, end of Aug. (20 yrs.) el.	7,608
b) Under Dry Cycle Conditions	
Maximum pool, approx. el.	7,568
Minimum, end of Aug. approx. el.	7,495
Average, end of June (14 yrs.) el.	7,527
Average, end of Aug. (14 yrs.) el.	7,517

Fluctuations With Ultimate Flows

a) Under Normal Cycle Conditions	
Maximum pool, approx. el.	7,633
Minimum pool, end of Aug. approx. el.	7,558
Average pool, end of June (21 yrs.)	7,617
Average pool, end of Aug. (21 yrs.)	7,612
b) Under Dry Cycle Conditions	
Maximum pool, approx. el.	7,585
*Minimum pool, end of Aug. approx. el.	7,505
Average pool, end of June (11 yrs.) el.	7,568
Average pool, end of Aug. (11 yrs.) el.	7,566

*Evacuation to the dead storage level referred to in the sponsor's statement would rarely, if ever, occur during the summer, recreational use season. Capacity table data indicate that such exhaustion of active storage would have been closely approached once during the period of study, late in April.

In the above table, present modified flows are adjusted to account for the depleting effect of all existing and authorized developments in operation. Ultimate flows are adjusted to account for the depleting effect of the system operating under ultimate development.

The above tabulation reveals that while the reservoir would seldom completely fill under ultimate flow conditions, nevertheless average summer pools could actually be somewhat higher than initially and that

average recreational use-season fluctuations would be quite comparable. In the light of present studies, therefore, it is believed that changing conditions resulting from ultimate Upper Colorado River Basin developments would not materially affect potential recreational values inherent in the reservoir. Nevertheless, it must be recognized that the effects of fluctuations on fishery will have, in either case, a direct bearing on general recreational importance.

Description of the site

The upper portions of the Black Canyon in which the dam would be located are less deep and, aside from a much reduced inner gorge, less precipitous and spectacular than the reaches embraced by the Black Canyon of the Gunnison National Monument a few miles below. The dam area, and gorge sections of the adjacent reservoir are not lacking, however, in notable scenic appeal, dominated as they are by rugged canyon country with quite spectacular buttes, darkly crowned with coniferous evergreens along the rim. Sapinero, Blue and Pine Creek Mesas flank the portals of the Canyon where it opens into the broader valley bordered by more gentle, rolling, open mesa terrain. This basin extends for some fifteen miles and will provide the most significant mass storage section of the reservoir.

Immediately above the small hamlet of Elkhorn, the valley again becomes restricted into a minor gorge a few miles in length, opening finally into the broader, comparatively flat-bottomed valley in which the town of Gunnison is located. On the basis of limited observation and in the absence of map material, it is very broadly estimated that the upper reservoir pool which would occupy the lower portions of this valley at high water would be some two or three thousand acres in extent. It would reach to within a few miles of Gunnison, and would be surrounded by low, gently rolling hills and mesa rangelands.

The general setting of the reservoir, in addition to immediate scenic values of considerable note at and above the dam, is superb. To the north lies the impressive West Elk Range, to the south the great San Juan uplift, and shortly to the east occurs the great continental divide, spectacular with alpine peaks often ranging over 14,000 feet in height. Many of these varying views, except in restricted gorge sections, would be visible from the reservoir itself.

Recreational values

The Gunnison River has long enjoyed a national reputation as an outstanding fishing stream. Anglers in great numbers are attracted to it annually, often from distant parts of the country. This recreational use must contribute appreciably to the economic stability of the valley above the Black Canyon of the Gunnison National Monument, and noteworthy investments have been made for guest and tourist accommodations. Many

such camps have been developed along the banks of the river which would be flooded by the Curecanti Reservoir. One disadvantage resulting from these developments, so far as the general public is concerned, has been the posting of many stretches of privately controlled stream banks.

Potential recreational use

Fluctuations in the reservoir during recreation use seasons except during drought periods will not, it is believed, be unfavorable for recreation. The area is located adjacent to U. S. 50, is near the spectacular Black Canyon of the Gunnison National Monument, and is surrounded by great Rocky Mountain areas which themselves offer recreational opportunities of a very high order. It appears reasonable to assume that the importance of the reservoir, as a complement to other advantages offered by the region, would assume a considerable degree of state significance, meeting a much wider range of recreational needs than presently exist in this comparatively thinly populated part of the state.

The extent to which lake fishing can be developed in lieu of the notable stream fishing which is now enjoyed will have considerable bearing on the popularity of the reservoir. Fluctuations which, because of seasonal occurrence, would not seriously impair general recreational values may complicate the maintenance of quality fishing, a phase of use which can best be analyzed by the Fish and Wildlife Service. In this connection, perhaps mention could be made of a suggestion which has been advanced regarding the possible construction of a large weir shortly below the upper basin by means of which a constant water level could be maintained in the large reservoir section near Gunnison. Should such an arrangement prove feasible, it would maintain an impressive pool under conditions which would be ideal for recreational use and presumably equally so for fish reproduction. This would greatly improve the basic values of the Curecanti Reservoir, even though at periods of low water, there would be two rather than one body of water. Because of seasonal occurrence this would not be a particularly unfavorable situation.

Even with moderately good "lake" fishing, the reservoir should encourage day, overnight and week-end use, and because of the location in relation to various mountain recreational areas, even vacation use should assume importance. As a natural concomitant to these types of visitor use, would be demands for summer home sites, probably group camp areas and notably for boating facilities. Early consideration should be given to planning the reservoir area, especially in connection with land acquisition, to meet various visitor needs in an orderly and well organized manner. It seems highly probable, as a result of the preliminary reconnaissance, that many areas suitable for the various types of development will occur in satisfactory relation to reservoir shores around both the central and upper basins.

Effect on Black Canyon of the Gunnison National Monument

No state park area will be affected by the reservoir. The interests of the National Park Service, however, will be adversely affected in the monument by regulation of river flows. How completely river regulation can be achieved by the Curecanti Reservoir is not, as yet, known, but it seems quite probable that it will reach a high degree and that only in comparatively rare years of excessive runoff would there be spills which would course through the Canyon in addition to normal regulated flows.

This regulation will drastically alter the historic flows through the Monument. These have already been somewhat changed by diversion to the Uncompahgre River basin by means of a tunnel taking off from the Gunnison River very shortly above the east monument boundary. The degree of regulation resulting from this diversion does not appear to have drastically changed the character of flows through the monument, with great rushing spring torrents, followed by minimum summer flows that are comparatively unimpressive. There are years of record, although very rare, when flow has practically ceased, leaving only scattered pools along the canyon bottom.

It is the historic flows which, over hundreds of millions of years, have carved the spectacular gorge down through the basic, precambrian geological formation to depths ranging from 1,730 feet to as much as 2,425 feet, creating a great earth gash which is, in places, deeper than the width from rim to rim. Other natural weathering forces have combined with the river to create this natural wonder. Spalls, chips, and gravels falling unhindered to the canyon bottom are annually swept away by the great spring tidal flushes of the river.

Evidently with the flow of the river regulated and equalized by the Curecanti Dam this annual spring "flushing" would no longer take place unless the dam could be operated in such a way as to release large volumes of water during flood periods. The National Park Service would, of course, be concerned with any development which would alter natural conditions in the monument.

National Park Service archeologists are of the opinion that only minor hunting and camp sites of archeological interest are likely to have been found in the basin, and not necessarily pre-historic.

Recommendations

The potential recreational value of the Curecanti reservoir indicates that appropriate attention should be given to land acquisitions, where public domain is not involved, in order to make adequate provision for the various recreational uses which can be anticipated.

Closely related to land acquisition problems will be routes selected for the relocation of U. S. 50 which will be necessitated by reservoir development. There is some indication that the south side will be followed by the new route. On either side, however, it is recommended that consideration be given to areas of potential recreational-use value, both to assure, so far as feasible, suitable access thereto from the highway and, of equal importance, to avoid undesirable relationship to such areas in a way to reduce their subsequent value. This will require early reservoir planning and close cooperation with the State Highway authorities.

It is especially recommended that consideration be given to possibilities of providing the weir in the narrow gorge between the lower and upper reservoir basins, by means of which a constant, or nearly constant water level could be maintained in the latter.

CRYSTAL RESERVOIR

The dam site for the Crystal Reservoir is located on the main Gunnison River, about one mile below the narrow Crystal Creek side draw which empties into the gorge from the north. The site is only a short distance above the east boundary of the Black Canyon of the Gunnison National Monument, Montrose County, Colorado.

The small Crystal Reservoir would function as an after-bay, re-regulatory impoundment for the very much larger Curecanti Reservoir, a few miles upstream. It would provide the means of developing important electrical energy, for which it is being considered. It would have no "holdover" storage function.

The following data is provided for this reservoir:

Planned capacity	40,000 a.f.
Maximum water surface el.	6,870
Minimum water surface el.	6,860
Normal water surface area	550 acres
Length of reservoir (estimated)	8 miles
Present stream bed el. at dam site	6,570
Dam height	305 feet

The sponsor has given assurance that operational plans for the reservoir contemplate a practically constant water level at full pool, power spills from the Curecanti unit being reused here for additional energy production. The capacity would be used only to provide power head and for daily regulation with drawdown limited to a maximum of less than 10 feet.

Description of the site

The reservoir area is entirely within the Black Canyon. Viewed from the air it lacks the sheer, precipitous character of the National Monument section which begins very shortly below the dam. The reservoir section, while yet extremely rugged, gives the impression of being a deep, very steep-sided "v"-shaped canyon. It is still 1,500 to 2,000 feet deep.

In addition to dam area access over construction and maintenance roads there will be one other point where limited access to the reservoir will occur. At elevation 6,870, the impoundment will extend a short distance up the Cimarron Creek side canyon, to within a few hundred yards or possibly a half a mile of U. S. 50. It was through this draw that the old Denver and Rio Grande Western Railroad from the west entered the Black Canyon. A bench mark elevation at the upper end of this draw is given as 6,893, only 23 feet above normal reservoir, clearly indicating the feasibility of water access at this point.

Potential recreational use

At present the some eight miles of the Gunnison River which would be inundated by the reservoir must have a high value for stream fishing, especially in view of the ready access to this part of the river noted above.

Lake fishing in the reservoir may reasonably compensate for the loss of stream fishing. The constant water level below several miles of the open stream between the Blue Mesa dam which would impound the Curecanti Reservoir and the headwaters of the Crystal may be factors which are favorable in this regard.

The reservoir should be interesting for boating--an interest which will be enhanced by fishing if it can be established and maintained. Even on its own merit, boating should have considerable appeal affording as it will views of the upper reaches of the scenic Black Canyon. Also, from near the dam, there may be glimpses into the more startling, precipitous sections of the gorge in the national monument below the reservoir. It is anticipated that facilities for boating, including sightseeing excursions, can be developed in the draw at Cimarron where the reservoir will closely approach U. S. highway 50.

The extremely steep, rugged nature of the canyon would probably preclude other forms of recreational use and development on the shores of the reservoir, forms of recreational outlets that can be more appropriately and conveniently developed on the great Curecanti Reservoir shortly up stream.

Effect on Black Canyon of the Gunnison National Monument

The monument and its primary values have been described by the National Park Service as follows:

> "Black Canyon is notable for its narrowness, depth, ruggedness, great expanses of sheer walls, and interesting gorge formation. The rims of the gorge are only 1,300 feet apart at their nearest approach, yet the gorge ranges from 1,630 to 2,425 feet in depth within the monument. At one location the channel of the Gunnison River narrows to only 40 feet in width. For many millions of years this river has been furiously carving its channel deeper and deeper through this probable Archean complex at a greater speed than all combined natural processes can widen it. The tools which the river uses are the sand and gravel that it carries, mainly in periods of flood. The hardness of its rock formation and the joint, or fracture, system account for the sharp, ragged sheerness of the canyon walls. The rolling hills, which rise above the canyon rim and which formerly entrenched the flow of the Gunnison River, are carved from sedimentary rocks. These rocks are so much younger than thos of the gorge itself, which immediately underlies them, that during this gap of time life developed from the single plant cell to the monstrous dinosaur. This tremendous break in the record of geological time is as significant to the imagination as the chasm of Black Canyon is to the sight."

It is true that regulated flows of the Gunnison River through the monument below the existing irrigation diversion tunnel have, for comparatively brief periods, been reduced to hardly more than scattered pools. But, without exception, these periods have been followed within the space of a few months with the great, furious spring torrents with their scouring effects that have, in the main, been responsible both for creating the spectacular gorge and deepening it. Regulation will have an adverse effect on this natural process.

With the Crystal Reservoir operated as a re-regulatory after-bay for the Curecanti Reservoir, additional effects on river flows through the monument should be negligible. On this basis it can be assumed that it will be the Curecanti which will affect the monument in this respect rather than the Crystal unit. Such changes in natural conditions, while very undesirable, are nevertheless not sufficiently adverse to offset the economic advantages to be gained by river regulation in the public interest.

Recommendations

In the event the Crystal Reservoir is developed, it is recommended that consideration be given to making suitable provision for boating facilities for the reservoir. This should include adequate land acquisition in the restricted area near Cimarron where the reservoir will be primarily accessible for such recreational activities.

FLAMING GORGE RESERVOIR

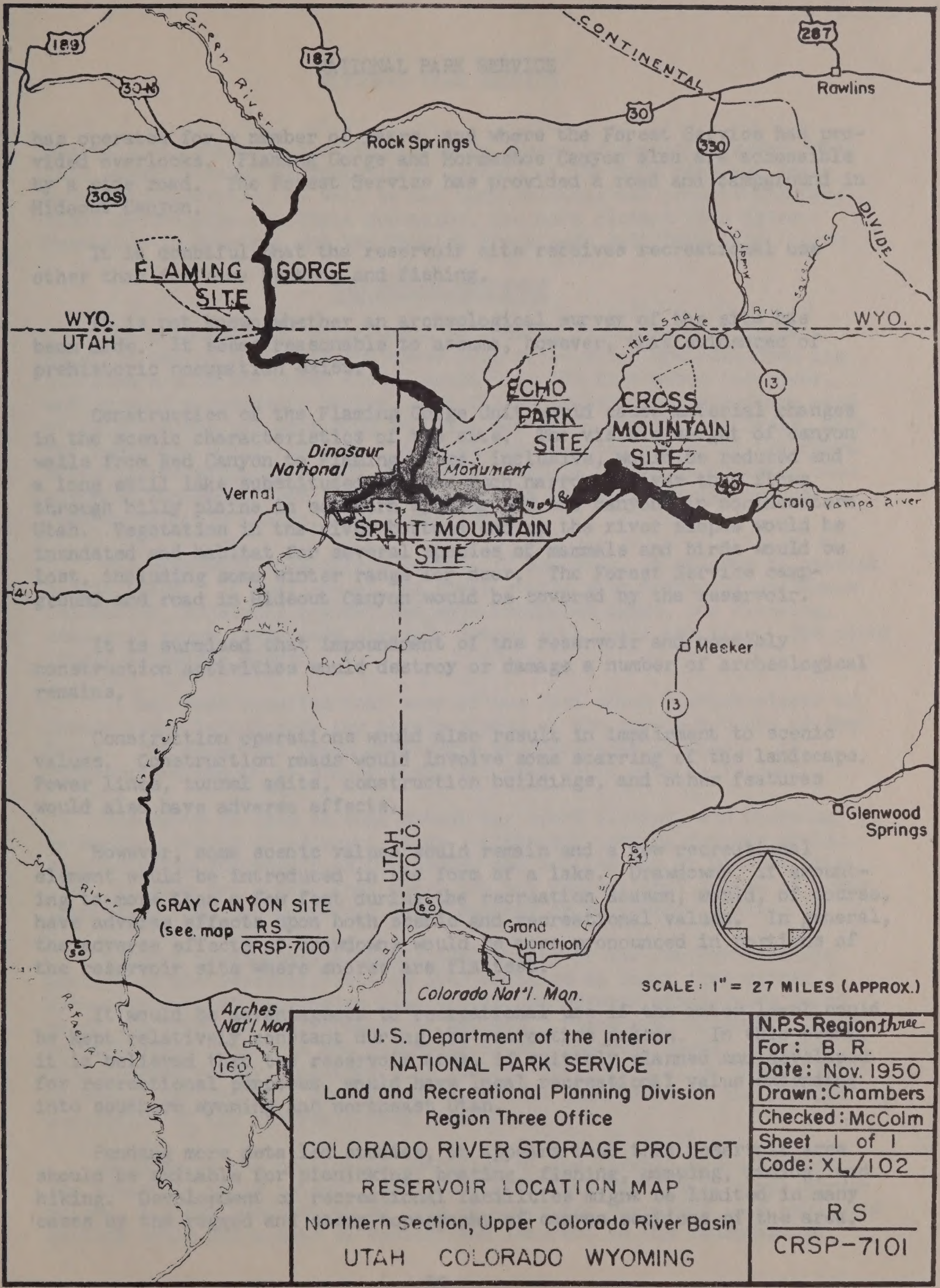
The proposed Ashley dam of the Flaming Gorge Unit would be located in Red Canyon at a point on the Green River about 32 river miles downstream from the Utah-Wyoming State line. It would rise 440 feet above the river and impound a reservoir having, when filled to capacity, a surface area of 40,800 acres and extending 91 miles upstream through Hideout Canyon, Kingfisher Canyon, Horseshoe Canyon, Flaming Gorge, and the rolling plains of southern Wyoming to a point within three or four miles of the city of Green River, Wyoming. The lower portion of the site lies in the Ashley National Forest on the northeastern flank of the Uinta Mountain Range. No primitive, wild, or wilderness area is involved.

Except for its area of origin in the Green River Lakes, the section of the Green River from Flaming Gorge to Red Canyon, inclusive, is the first highly scenic portion of the river in its course to its junction with the Colorado River. Farther downstream it plunges into the much more spectacular canyons of Dinosaur National Monument.

From Red Canyon upstream to Flaming Gorge is a nearly continuous series of canyons, of which the two named are the more scenic. Many portions of Red Canyon are narrow, precipitous, and colorful, its colors being reminiscent of the reds, grays, and purples found in the Canyon of Lodore in Dinosaur National Monument. It attains a depth of 1,500 feet or possibly more. The slopes are partly forested while the rims are more heavily wooded.

Flaming Gorge is notable for the intense reddish and orange shades of its cliffs which rise abruptly several hundred feet above the river. The colorful cliff on the right bank continues in a southwesterly direction and merges with the northerly slopes of the Canyon of Sheep Creek, a tributary. The cliff forms a finely colored setting for the Green River where, after leaving Horseshoe Canyon, it makes a sharp bend in Nielson Flat before entering Kingfisher Canyon.

The canyons are locally well-known for their scenic values, and as features of interest to visitors to the Uinta Mountains. Utah State Highway No. 44 runs from Vernal to a point a few miles from the dam site. Unimproved roads lead southward from Green River, Wyoming, to join this road. A side road leads to the rim of the canyon where a small resort


189
187
Green River
CONTINENTAL
DIVIDE
287
Rawlins
30-N
30
Rock Springs
330
30S
FLAMING GORGE SITE
WYO.
UTAH
WYO.
COLO.
Little Snake River
Savery Cr.
Muddy Cr.
13
ECHO PARK SITE
CROSS MOUNTAIN SITE
Dinosaur National Monument
Vernal
40
Yampa R.
Craig
Yampa River
SPLIT MOUNTAIN SITE
40
White River
Meeker
13
UTAH
COLO.
Glenwood Springs
6 24
Green River
GRAY CANYON SITE (see map RS / CRSP-7100)
50
Grand Junction
Colorado Nat'l. Mon.
Colorado R.
Arches Nat'l. Mon.
San Rafael R.
160
SCALE: 1" = 27 MILES (APPROX.)

U.S. Department of the Interior
NATIONAL PARK SERVICE
Land and Recreational Planning Division
Region Three Office
COLORADO RIVER STORAGE PROJECT
RESERVOIR LOCATION MAP
Northern Section, Upper Colorado River Basin
UTAH COLORADO WYOMING

N.P.S. Region three
For: B. R.
Date: Nov. 1950
Drawn: Chambers
Checked: McColm
Sheet 1 of 1
Code: XL/102

RS
CRSP-7101

has operated for a number of years, and where the Forest Service has provided overlooks. Flaming Gorge and Horseshoe Canyon also are accessible by a side road. The Forest Service has provided a road and campground in Hideout Canyon.

It is doubtful that the reservoir site receives recreational use other than for some hunting and fishing.

It is not known whether an archeological survey of the site has been made. It seems reasonable to assume, however, that evidences of prehistoric occupation exist.

Construction of the Flaming Gorge Unit would cause material changes in the scenic characteristics of the site. The visible height of canyon walls from Red Canyon to Flaming Gorge, inclusive, would be reduced and a long still lake substituted for the much narrower river that flows through hilly plains in southern Wyoming and the canyons in northeastern Utah. Vegetation in the river bottoms and up the river slopes would be inundated and habitat for several species of mammals and birds would be lost, including some winter range for deer. The Forest Service campground and road in Hideout Canyon would be covered by the reservoir.

It is surmised that impoundment of the reservoir and possibly construction activities would destroy or damage a number of archeological remains.

Construction operations would also result in impairment to scenic values. Construction roads would involve some scarring of the landscape. Power lines, tunnel adits, construction buildings, and other features would also have adverse effects.

However, some scenic values would remain and a new recreational element would be introduced in the form of a lake. Drawdowns, if amounting to more than a few feet during the recreation season, would, of course, have adverse effects upon both scenic and recreational values. In general, the adverse effects of drawdowns would be more pronounced in portions of the reservoir site where shores are flattest.

It would be advantageous to recreational use if the water level could be kept relatively constant during the recreation season. In this event, it is believed that the reservoir area, if suitably planned and developed for recreational purposes, would have local recreational value extending into southern Wyoming and northeast Utah.

Pending more detailed studies, it appears that this reservoir area should be suitable for picnicking, boating, fishing, camping, riding, and hiking. Development of recreational facilities might be limited in many cases by the rugged and steep topography of canyon sections of the area.

Recreational planning for Flaming Gorge Reservoir should, however, take into consideration the competitive effects of the Echo Park and Split Mountain Reservoirs, as well as the many existing and potential attractions in the adjacent Uinta Mountains, the more distant Wind River Mountains in Wyoming, and the Wasatch Front near Salt Lake City.

CROSS MOUNTAIN UNIT

The proposed dam, which would be located at the head of Cross Mountain Canyon on the Yapmpa River 58.5 river miles upstream from its confluence with the Green River, would rise 295 feet above the river, and impound a reservoir having, when filled to capacity, a surface area of 52,200 acres and extending 76 miles nearly to the city of Craig, Colo. The reservoir would inundate the broad and indented valley of the Yampa River to the vicinity of the village of Maybell. Here it would be constricted somewhat; from this point it would extend easterly through Juniper Mountain Canyon, then widen again.

The reservoir site offers little, if anything, in the way of special scenic value. It consists of the river course with bordering deciduous vegetation, adjoining meadows and some irrigated lands, and flanking, semi-arid rough grasslands sparsely dotted with cedar and pine. The river itself is fairly clear.

It has been reported that some of the last known resting places of Canada geese in Colorado may be along some of the bars and banks of the Yampa. The reservoir would apparently inundate some of these. An undetermined amount of winter range for deer would also be flooded.

The river is used to some extent for sport fishing, and there may be hunting values in adjacent lands. Although, pending further study, no conclusive statements as to fishing and hunting can be made at this time, it does not appear that there are any recreational values of great importance that the reservoir would destroy or seriously impair.

A brief preliminary archeological survey of the Juniper Mountain portion of the reservoir site in 1942 revealed at least five rather extensive prehistoric Indian camp sites, and several others were noted along the river in the vicinity of Maybell. There are, no doubt, other archeological values in the remainder of the reservoir area. However, an intensive survey, together with limited testing, will be necessary to determine the probable extent and scientific importance of the prehistoric occupation of the reservoir area as a whole.

Because of the monotonous character of the terrain through which the reservoir would extend, this artificial lake would have minor scenic value. A long, somewhat broad lake of irregular shoreline in a semi-arid setting would add a note of variety and interest to the landscape in

normal or above-normal runoff cycles. If, during low runoff cycles, use of the active storage were to result in considerable drawdowns, these would adversely affect scenic values and this effect would progress with the reduction in storage. Large expanses of barren shores would probably be exposed, leaving mud flats and rough cobble beaches. Drawdowns would impair recreational values of the reservoir, the degree of impairment depending on the extent of drawdown.

In years of normal or above-normal runoff, the reservoir can be expected to offer possibilities for recreation, such as picnicking, boating, camping, and perhaps hunting and fishing. It may provide opportunities for local day use by residents of Craig, Colorado, and vicinity. More thorough study would be required to conclude as to probable use from more distant population areas, such as Denver and Grand Junction, Colorado; Salt Lake City and Vernal, Utah, Rock Springs, Rawlins and Laramie, Wyo. Recreational planning for this reservoir should take into consideration the competitive effects of other reservoir areas such as Echo Park, Split Mountain, Flaming Gorge, and Pathfinder-Seminoe in Wyoming, as well as mountain areas in this general part of Colorado-Wyoming-Utah region.

ECHO PARK AND SPLIT MOUNTAIN UNITS

Dinosaur National Monument was established by proclamation of President Wilson on October 4, 1915, under authority of the Antiquities Act for the primary purpose of preserving a rich deposit of fossilized dinosaur bones which had been found here in an excellent state of preservation. By President Roosevelt's proclamation of July 14, 1938, the monument was enlarged to include other resources of geological, archeological, and wilderness values. The extension included the Canyon of the Yampa River and the Canyon of Lodore, Whirlpool Canyon, and Split Mountain Canyon on the Green River. Of the total gross area of 209,744 acres, about 70% is in Colorado and about 30% in Utah.

The enlarged monument is essentially a canyon-plateau area along the most spectacular and scientifically interesting parts of the drainage of the Green River and its major tributary, the Yampa. The dynamic processes of river erosion have produced a colorful, rugged wilderness of deep canyons, dissected erosional benches, and bold promontories. The geological features have been given the place of outstanding importance. Second to these are the scenic features which form an inseparable combination with those of geology.

Functionally, Dinosaur National Monument consists of two sections referred to as the Quarry Section and the Canyon Section.

The Quarry Section comprises a comparatively small area in the vicinity of the dinosaur beds and includes the original monument. The Canyon Section, consisting of the remainder of the present monument, is over 200,000 acres in extent.

The geologic formations of the Quarry Section are of scientific importance and of distinct scenic value, but the major significance of this section is considered to be in the dinosaur beds. The principal deposits of fossilized dinosaur bones are found in the coarse sandstones of the Morrison (Jurassic) formation which underlies the shales and sandstones of the Cretaceous and is underlain by other strata of the Jurassic.

The Canyon Section is characterized by a notable combination of geological, scenic, archeological, and biological values and by its wilderness quality. Its most spectacular features are the canyons of the Green and Yampa Rivers, where interesting geological formations and impressive landscapes are displayed in great variety. One of the exceptional attributes of this section consists of contrasts of these two canyons in their geological formation and scenic character. Echo Park, at the confluence of the Green and Yampa Rivers, is especially notable because of the high, knife-ridge of sandstone known as Steamboat Rock, which rises vertically about 750 feet above the junction of the Green and Yampa Rivers.

In addition to the predominant geologic and wilderness values of the Canyon Section, there are noteworthy archeological features. Evidences of prehistoric Indian life have been found in many areas and include camp sites, rock shelters, petroglyphs, burials, and caves that were inhabited or used for storage. The archeology of the region is not yet fully known nor have all sites been adequately investigated and recorded.

Likewise, the many interesting historical aspects of the area have not been adequately chronicled.

In addition, there are distinct biological interests. Deer are abundant in some sections, and there have been reports of mountain sheep. There are also many plant associations which are correlated with geological structure and interesting biotic units whose origins are related to the development of the canyons and the local mountain structures on the flank of the Uinta Mountains. Forms of animal and plant life reveal influences of the hardy climate and are evidences that much of interest might be revealed by a careful biologic survey.

The proclamation of July 14, 1938, enlarging the monument, stated that "The Director of the National Park Service, under the direction of the Secretary of the Interior, shall have the supervision, management, and control of this monument as provided in the act of Congress entitled 'An act to establish a National Park Service, and for other purposes,' approved August 25, 1916, 39 Stat. 535 (U.S.C. title 16, secs. 1 and 2) and acts supplementary thereto or amendatory thereof, except that this reservation shall not affect the operation of the Federal Water Power Act of June 10, 1920 (41 Stat. 1063), as amended, and the administration of the monument shall be subject to the Reclamation Withdrawal of October 17, 1904, for the Brown's Park Reservoir Site in connection with the Green River project."

NATIONAL PARK SERVICE

In accordance with the act of 1916, it has been and is the responsibility of the National Park Service to conserve the scenery and the natural and historic objects and wildlife within the areas in the National Park System, and to provide for the enjoyment of them in such manner and by such means as will leave them unimpaired for future generations. Accordingly, the major aims of the National Park Service in its administration of the Dinosaur National Monument have been:

1. Protection of unimpaired resources and, through elimination of factors that have modified other natural conditions, the restoration of those other conditions to their original state. The modifying factors principally involved are agricultural pursuits which consist largely of grazing, and the presence of non-Federal lands within the exterior boundaries of the area.

2. Protection and preservation of archeological features.

3. Provision of facilities necessary to enable visitors to study and enjoy the features of paleontological, geological, archeological, wilderness, and related interests, and required for proper recreational use and administration of the area.

In accordance with those objectives, the National Park Service prepared a master plan for Dinosaur National Monument. The developments shown thereon were for the purposes of making the noteworthy features of the area accessible and providing facilities and accommodations for visitors, as well as administering the area and protecting its superb natural and archeological values. The general theme of development was centered around the paleontology of the Quarry Section and the wilderness character of the Canyon Section. Proposed facilities included a modern road system, an expanded trail system, several tourist centers, and a headquarters area.

In connection with investigations of the Colorado River Basin under authority of the Federal reclamation laws and acts amendatory thereof or supplementary thereto, particularly the Boulder Canyon Project Adjustment Act of July 19, 1940(54 Stat. 744), the Bureau of Reclamation has studied for several years the water storage and hydroelectric power possibilities of the upper Colorado River Basin including the area included within Dinosaur National Monument. The Bureau arrived at the conslusion that utilization of two storage-power sites within the national monument, referred to as the Echo Park and Split Mountain sites, was necessary for the best development of the water resources of the Colorado River Basin and that suitable alternate sites outside the boundaries of the monument could not be found.

In its role, under Congressional mandate, as custodian of the areas of the National Park System, of which Dinosaur National Monument is one,

the National Park Service believes and therefore maintained that the proposed Echo Park and Split Mountain Units of the Upper Colorado River Storage Project would seriously and adversely affect numerous splendid natural and archeological values of the extensive canyon portions of the national monument, although they would not physically affect the small area in which the famous dinosaur beds are found. On pages 244 and 245 of the Departmental report of July 1947, entitled The Colorado River Basin, and in the National Park Service report entitled A Survey of the Recreational Resources of the Colorado River Basin, compiled in 1946 and published in 1950, it is asserted that the effects of the proposed Echo Park and Split Mountain Units upon irreplaceable geological, wilderness, and related values of national significance would be deplorable.

The former report also stated that some geological and scenic values would remain, that new scenic and recreational values would result from the impoundment of reservoirs, and that, even though they would not compensate in kind for the losses described in the report, they would be of real importance.

Both reports pointed out that the policy of the National Park Service as the administrative agency responsible for the national monument has been to make the protection of the natural and archeological values of the area the controlling factor in administering it. They also expressed the view that the question of whether this policy is to be changed to permit development for water-control would require for its solution a review of all probable advantages and disadvantages by authorities superior to either the National Park Service or the Bureau of Reclamation, and that, before changes in the status of the Canyon Section are authorized in order to recognize water control as the principal consideration in administering the unit, it should have been clearly and certainly shown that it would be in the greater national interest to develop the area for such use than to retain it in its natural state for its geologic, scenic and associated values and for the enjoyment of them by the Nation.

The proposal to construct the Echo Park and Split Mountain dams within Dinosaur National Monument resulted in a controversy of nationwide scope. There were numerous conservation groups and individuals on the one hand who believed that the effects of these projects upon the canyon areas of the national monument would be so disastrous as greatly to impair and even destroy natural values of the highest order and that suitable alternate sites could be found outside the monument to save the area from despoilation. There were also many groups and individuals on the other hand who believed that utilization of the two sites in question was necessary for the fullest development of the power resources of the Colorado River and that satisfactory alternate sites outside the monument did not exist. The controversy became so intense that the Secretary of the Interior decided to hold a public hearing in Washington, D. C., on April 3, 1950, to afford both sides an opportunity to state their views.

After thorough study of the arguments of opponents and proponents of the projects, the Secretary on June 27, 1950, issued a memorandum to the Commissioner, Bureau of Reclamation, and the Director, National Park Service, as follows:

"THE SECRETARY OF THE INTERIOR
WASHINGTON

June 27, 1950

Memorandum

To: Commissioner, Bureau of Reclamation
Director, National Park Service

From: The Secretary

Subject: Construction of Dams in the Dinosaur National Monument

The preparation of a comprehensive report for the development of the Upper Colorado River Basin has posed the question of whether Echo Park (immediately) and Split Mountain (eventually) Dams should be built in the canyon sections of Dinosaur National Monument. I will not have the final say, but I must determine whether, as Secretary of the Interior, I shall approve and recommend to the Congress a plan that includes these dams.

The history of the issue is well known to you and is well-documented in the transcript of proceedings of the hearing I held on April 3, 1950. I shall not review it here.

I am impressed with the fact that the waters of the Colorado River constitute a resource of paramount importance to the region and that in view of the arid nature of the area, my approved plan for the development of the Upper Basin must make every practicable provision for the conservation and multiple use of these waters in the interest of the people of the West and of the whole nation.

I am not unmindful of the public interest in the inviolability of our National Parks, and in the status, only a little less austere, of the National Monuments. By no precedent of mine would I wish to endanger these places.

Weighing all the evidence in thoughtful consideration, I am impelled in the interest of the greatest public good to approve the completion of the Upper Colorado River Basin Report, including the construction of the dams in question, because:

(a) I am convinced that the plan is the most economical of water in a desert river basin and therefore is in the highest public interest; and

(b) The order establishing the extension of the monument in the canyons in which the dams would be placed contemplated use of the monument for a water project, and my action, therefore, will not provide a precedent dangerous to other reserved areas.

I note that the fossils are not in the areas of the monument proposed to be flooded and that the creation of the lakes will aid the public in gaining access to scenic sections of the Green and Yampa River canyons. Much superb wilderness within the monument will not be affected, excepting through increased accessibility.

The importance to the growth and development of the west of a sound Upper Colorado River Basin program can scarcely be overemphasized. I hope that this decision on my part will promote quick solution of all other problems connected with this matter so that we may proceed with such a program.

I ask the National Park Service and the Bureau of Reclamation to cooperate fully in making plans that will insure the most appropriate recreational use of the Dinosaur National Monument, under the circumstances.

(Sgd.) Oscar L. Chapman

Secretary of the Interior"

Accordingly, the National Park Service is making a restudy of the values of the area in line with the Secretary's decision to recommend to Congress the construction of the Echo Park and Split Mountain Units. The objective of the restudy will be the replanning of proposed development, especially of the Canyon Section, to make the best possible recreational use of the Echo Park and Split Mountain Reservoir areas, in the event the dams are authorized, as well as to protect and make accessible remaining features of natural and archeological interest.

Recreational planning for the Echo Park and Split Mountain Reservoir areas will be based on the assumption that the Congress will approve and provide funds for them and will be focused on the potential values of these two artificial lakes and adjoining lands for such activities as boating, fishing, swimming, hiking, and riding. These will require roads and trails to points of access on the reservoirs and to overlook or view points. Consideration will also be given to needs for overnight facilities including campgrounds. Moreover, planning for the administration of the area will receive careful study. This will include studies for

the safety of visitors and the protection of the area itself against soil erosion and fire, as well as plans for an administrative, protective, and interpretive staff and headquarters.

Prior to filling the reservoirs, it is contemplated that more thorough studies of the archeology, paleontology, geology, and wildlife of the area will be made, particularly for the purpose of recording and/or salvaging important scientific data which would be submerged by the reservoirs. The information gained by these studies will be of great value in future interpretive programs for the recreational areas.

The National Park Service will cooperate with the Bureau of Reclamation with regard to the location and layout of the Bureau's permanent and temporary facilities, such as construction camps, roads, tunnels, power lines, and administrative developments, so that the objectives of the two agencies may be most harmoniously realized. Such cooperative planning should also result in the ultimate combined use of some facilities, such as roads, for both administrative and recreational purposes.

Estimates of Cost

Recreational development of the Canyon Section of Dinosaur National Monument has been impossible because of inadequate funds or other obstacles. Necessarily such developments were deferred during the war period and there has been no opportunity thus far during the post war period to proceed with logical and needed development. The Canyon Section is, therefore, inaccessible to the great majority of visitors. Trips into this section have been made almost solely by local residents and a few others who are sufficiently familiar with this type of rough canyon-plateau country to venture into it over very rough "roads" and trails.

It is believed, however, that there will be considerable demand to develop the Canyon Section for recreational purposes. Its location between two heavily used transcontinental highways, U. S. 30 and U. S. 40, and possibilities for making it accessible by good roads from both lead to the conclusion that this area, if suitably developed, will receive a good deal of use, not only by residents of nearby portions of Colorado, Utah, and Wyoming, but also from more distant and more heavily populated districts. While the small number of potential visitors living within the immediate vicinity do not require extensive developments, the number of visitors from more distant sections may be expected to be large and a considerable recreational development will therefore be necessary.

In order to reach final conclusions as to the probable annual number of visitors to the area under adequate recreational development, it is essential to undertake a study involving not only these two reservoirs but also the recreational, scenic, and related resources, existing and potential, of the general region in which these reservoir areas lie.

This region includes at least southwestern Wyoming, northwestern Colorado, and northeastern Utah. A regional study is imperative before it can be fully determined how much and what kinds of recreational use will be made of the two reservoir areas and, therefore, the amount and types of recreational facilities that should be provided.

Among the important resources of the region to be fully studied are the existing attractions of the nearby Uinta Mountains including forest recreation in the scenic Ashley and Wasatch National Forests with their natural lakes and streams and good fishing, as well as the cooler summer climate of the Uintas. Also, to be seriously considered is the potential recreational value of the Flaming Gorge reservoir area, particularly in view of its close relationship with the Uinta Mountains and their forests and natural waters. If, as seems contemplated by the Bureau of Reclamation, a good road may be constructed between U. S. highway 4~~3~~0 at a point near Vernal, Utah, to U. S. highway3~~4~~0 in the vicinity of Green River or Rock Springs, Wyoming, by way of the Ashley dam of the Flaming Gorge Reservoir, a large and important mountain recreational district including this reservoir will apparently be made readily accessible.

Also to be considered is the Cross Mountain reservoir area, particularly if the fishing proves good.

This regional study has been initiated by the National Park Service, and it is expected that its findings will be made and its conclusions reached within a few months. These will have a direct bearing upon final recreational planning of the Echo Park and Split Mountain reservoir areas. Pending the completion of this study, the National Park Service has preparec preliminary estimates of cost for Echo Park and Split Mountain, recognizing the possibility, however, that material alterations may have to be made in them when the regional study has been finished. The current estimates follow:

1. Preliminary planning

For study of boundary problems, selection of sites and preliminary sketches for development, soil conservation studies for watershed protection, collaborating with Bureau of Reclamation personnel on location of construction roads, camps, stockpiles, borrow pits, power lines, and architectural design of structures, etc., preparation of the master plan which includes the development outline and all pertinent drawings as called for in Volume 12 of the National Park Service Administrative Manual, travel, per diem, and incidental expense $100,000

NATIONAL PARK SERVICE

Headquarters:

This development will include administrative offices, repair shops, equipment storage buildings and seven employees' residences. Current studies indicate that the logical place for such development may be on U. S. highway 40 at a point where the proposed main approach road will lead from the highway to the interior of the Canyon Section. Related to administrative headquarters will be several ranger stations throughout the area for services to visitors and protection of the area itself against fire. 1,800,000

Construction cost $15,800,000

Construction Plans, Specifications and Estimates

Planning and supervision of construction average approximately 12% of construction cost 1,896,000

1,896,000

GRAND TOTAL PLANNING AND CONSTRUCTION $17,796,000

3. Wildlife Program

a. To survey the existing terrestrial animal life of the area to be flooded and the adjoining habitats which will be affected and to plan for subsequent management and interpretation $17,000 p.a.

b. To survey the existing fishery resources and to plan for management and public use of the fishery in the future impoundments 10,000 p.a.

c. To survey the existing plant life of the areas to be flooded and affected by flooding, and to plan for subsequent management, use by wildlife and interpretation to the public 10,000 p.a.

A minimum of three years will be required for the necessary field investigations and writing reports. Total amount required $111,000

4. Geological program

a.	To excavate two important dinosaur sites in Echo Park and Split Mountain respectively; recovery, preservation, and storage of artifacts and plan for subsequent public exhibit	$25,000 p.a.
b.	To survey geologic values of area, prepare geologic maps, and develop future interpretive programs	10,000 p.a.

A minimum of two years will be required for the necessary field investigations, writing and printing reports. Total amount required 70,000

5. Archeological program

a.	Intensive survey of Yampa and Green River Canyons and testing of new sites as located	50,000
b.	Complete excavation of Hell's Midden	20,000
c.	Complete excavation of Mantle's Cave	8,000
d.	Intensive testing of 33 other sites of the total 58 at approximately $3,000 per site	99,000
e.	Archeological excavation under (a.) and (d.) after survey and testing are completed	200,000
	Total	$377,000

A minimum of three years should be allowed for adequate completion of this project

GRAND TOTAL $18,354,000

*Program of Estimated Planning, Construction, and Related Costs, by Fiscal Years
Echo Park and Split Mountain Units, Colorado River Storage Project, involving Dinosaur National Monument

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Totals
Plans and Investigations											
Pre-project recreational investigations and studies, archeological, geological, wildlife and soil and moisture studies; master plan preparation, detail construction drawings and estimates and related work	$212,000	$399,000	$ 443,000	$ 300,000	$ 400,000	$ 300,000	$ 300,000	$ 200,000			$ 2,554,000
Construction and Land Acquisition											
Roads and trails, buildings and utilities, etc. including acquisition of land needed for recreational use and development			$1,000,000	$2,200,000	$3,500,000	$3,140,000	$1,900,000	$1,650,000	$1,310,000	$1,100,000	$15,800,000
Totals	$212,000	$399,000	$1,443,000	$2,500,000	$3,900,000	$3,440,000	$2,200,000	$1,850,000	$1,310,000	$1,100,000	$18,354,000

*Prepared by River Basin Recreation Survey, Region 2
November 14, 1950

BUREAU OF LAND MANAGEMENT

The Bureau of Land Management is charged with responsibility for managing, developing, protecting, and disposing of the surface and subsurface resources of the vacant, unappropriated public domain lands of the United States, as well as the mineral resources of public lands withdrawn for other agencies. It has the exclusive responsibility for cadastral surveys on the public lands. It acts as custodian and handles applications for all mineral resources, not only on all public lands, but also upon privately owned lands where mineral rights are retained by the United States. The Bureau is the office of record of all transactions involving the public lands of the United States. It processes withdrawals of the public domain lands for administration by other federal agencies, and it classifies the remaining lands for their highest use, and administers them according to such classification. The Bureau rules on all applications to enter the public land under the agricultural land laws and, when proper, issues patents to the land. The Bureau handles the grazing responsibilities of the former Grazing Service under the Taylor Grazing Act of 1934, regulating grazing on the federal range within the grazing districts and on lands leased for grazing outside of the grazing districts.

From the above general statement of the responsibilities and activities of the Bureau of Land Management in the Upper Colorado River basin, it is apparent that any changes in the general economy and land pattern of the area will have a strong influence on the program of the Bureau of Land Management. The Colorado River Storage Project and subsequent irrigation projects will have far-reaching beneficial effects on the local economy, making it necessary to make substantial adjustments in public land programs for the Basin.

There remains in the Upper Colorado River basin approximately 29 million acres of public domain, most of which is included in established grazing districts. Approximately 41 percent of the gross area of the basin is administered by the Bureau of Land Management. The acreages of public domain are distributed by States about as follows:

State		Acres
Arizona		156,000
Colorado		6,610,000
New Mexico		1,749,000
Utah		13,904,000
Wyoming		6,582,000
	Total	29,001,000

BUREAU OF LAND MANAGEMENT

The public domain consists of remnants of a land disposal program which has continued for almost a century. These lands are therefore the least productive and those which are located in arid regions where crops cannot be produced without extensive investment in irrigation. While these lands have been considered mainly valuable for grazing, industrial development and irrigation have created a demand for lands which were formerly considered as having no value. Their disposal to individuals and to public programs continues to take place. In addition to those being withdrawn for reclamation purposes, numerous applications are filed each year for homesteads, isolated tract sales, home, cabin and business sites, and various other special uses. Public lands are exchanged for State and privately owned lands where such exchanges are in the public interest. Those lands which have natural recreational or scenic value, or acquire these values through construction of artificial dams, may be reserved for use by State, municipal, or Federal agencies dedicated to the management and development of land for these uses.

The principal use of the public domain at the present time is grazing. These same grazing areas are subjected to multiple uses, including production of forest and woodland products and big game. Another important value attaching to the public domain is its watershed value. The public domain lands are not the principal water producing lands, but they do contribute the major portion of the sediment deposited in the Colorado River. An analysis of the sediment records available on the Colorado River shows that approximately 60 percent of the sediment entering the stream originates in the area located below the confluence of the Green and Colorado Rivers and above the Grand Canyon. Another 22 percent originates in the San Juan River drainage above the Bluff gaging station. The total water contribution from these two areas is about 25 percent of that passing the Grand Canyon. In these two areas we have a situation where 80 percent of the sediment is contributed by 25 percent of the water. Seventy-five to eighty percent of the land in these two areas is federally owned.

With the development of the Upper Colorado River it is imperative that broad studies be made which will provide information to determine the proper use of land and water resources as a basis for determining disposal programs and adjustments in land control between federal agencies. Such studies would form the basis for developing an integrated land-use program which would have as its objective a balance between the various phases of agricultural pursuits as well as mineral development and other industries. These studies should be on an area basis to insure proper consideration of the present and potential uses of land and water in advance of action programs. For example, livestock raising is one of the most important industries in the Upper Colorado River basin and is successful only where

there is a proper balance between feed produced on irrigated land and on the open range. Advance area studies are needed to avoid a situation where this balance is not maintained thereby causing overgrazing and accelerated erosion.

The effect of the Upper Colorado River storage and participating projects on the program of the Bureau of Land Management is specifically outlined below under the various functions of the Bureau.

MINERALS AND RESOURCE DISPOSAL

There are in the public domain lands extensive deposits of coal, oil and gas, and numerous other minerals. Notable examples are the coal fields throughout the Basin and oil and gas deposits in the San Juan and Uintah basins and in northwestern Colorado near Rangely.

The Bureau of Land Management is charged with the responsibility of processing applications for leases of oil, gas, coal, phosphate, potash, etc., under the Mineral Leasing Act of February 25, 1920, as amended, and applications for mineral entries; of determining whether the public land is mineral or non-mineral in character, as well as making investigations of mining claims to determine the validity of such claims. The hydroelectric power made available as the result of the Colorado River storage project will greatly stimulate the development of mineral resources, making it necessary for the Bureau of Land Management to adjust its operation to meet changing programs. The number of mineral applications is expected to increase manyfold. The added work connected with investigating and determining the validity of existing mining claims in connection with the construction program will be one of the immediate jobs of the Bureau of Land Management. There will also be a large amount of appraisal work of valid mining claims on lands which will be inundated as a basis for determining damage to claimants. The costs of this accelerated program resulting from the Upper Colorado storage project are reflected in the attached budget estimates under "Mineral Examinations."

LAND CLASSIFICATION AND RESOURCE INVENTORY

Prior to designating public land for certain uses or acting upon applications seeking to acquire part of the public land, the law requires that the land be classified according to its suitability for the purpose intended. This includes determining that the lands are proper for withdrawals for National Forests, Parks, Wildlife Refuges, and Reclamation. Coincident with and a part of the land classification responsibilities of the Bureau of Land Management is the determination of which lands the public interest requires be retained in public ownership, and the planning of a unified management program which

encourages the most productive use of these lands from a public viewpoint. Proper management encompasses policies dealing with multiple land uses such as forestry, grazing, mining, watershed protection, and recreation. Land classification also encompasses economic studies as a basis for determining the relationship between land pattern, public improvements, private improvements, the different phases of agricultural pursuits, and potential and existing industrial development.

The classification of the public lands in the Colorado River basin has been carried out on a basis of relatively small areas, chiefly those on which land disposal cases are pending. The initiation of the Colorado River Storage Project, with the subsequent development of the participating projects, will make it imperative that the program of the Bureau of Land Management on land classification and resource inventories be stepped up manyfold if errors are to be avoided in the over-all land-use program of the Upper Colorado River basin.

The character of the public domain is known in a general way, but sufficient information is not available on which to base sound land management plans or to determine the over-all land-use adjustments needed. Detailed physical and economic information is needed to determine the suitability of public lands for such uses as watershed, forestry, grazing, crop production, industrial, recreational, and other special uses. A general resource inventory is needed, which would include the segregation of the lands according to their physical use capabilities as limited primarily by soil, topography and climate.. Such a study would appraise the erosion situation as to extent and degree and would include an inventory of the forage and timber resources as to quantity and quality to serve as a basis for stocking the range and determining allowable cut of timber and woodland stands. The data collected in such an area study would serve not only as a basis for planning conservation and watershed protection, but would permit an analysis as to which lands, in the public interest, should be retained and which lands should more properly be managed by other Federal agencies or under private ownership. It will permit a complete analysis of interrelated land values. When analyzed in connection with expected agricultural and industrial development as a result of the development of the Upper Colorado River basin, such a survey will indicate what adjustments will be needed for a balanced economy in the Basin.

Such a broad area classification and resource inventory should be initiated at an early date, as the data developed should be available in advance of completion of construction phases. The estimated cost of an area classification and resource inventory is reflected in the attached schedule.

BUREAU OF LAND MANAGEMENT

BASIC LAND RECORDS

The Bureau of Land Management is charged with the responsibility of keeping the basic land records for the public lands of the United States. This activity is carried on through the Bureau's various land offices. In these offices are recorded all applications for entry upon public lands for any purpose except grazing permits within established grazing districts. Among other kinds of entries, these include homestead entries, desert land entries, small tracts, isolated tracts, exchanges, special-use, state selections, grazing leases, mineral and gas and oil leases. Records must be maintained on the final disposition of all of the above enumerated applications, including patents issued and patented lands on which the minerals are reserved to the United States. The combined record of all of these entries is the only means of determining current status of the land. Records are also kept of all lands withdrawn for use by other federal agencies, as well as rights-of-way over public lands. Records of revocation of various orders withdrawing lands are also maintained as a basis for determining the availability of land for other uses.

The development of the water resources of the Upper Colorado River and the resulting rapid industrial development through the Upper Colorado River storage project and participating projects, will greatly increase the demand for public lands in the Basin. The increased number of land transactions will increase the volume of work in the land offices beyond the capacity of the present facilities and personnel, and the present record-keeping system. Lands involved in both the storage project, and the lands which will be irrigated under participating projects, will have to be cleared of all other obligations against the land. This will require a review of all existing withdrawals, including those which overlap, and the mineral claims on the lands affected. Since mineral claims are not filed in the land office until patent is applied for, this will require extensive checks in the various county offices as well as the Federal land offices. The estimated cost of this project is shown in the attached tabulation giving the estimate of funds needed.

CADASTRAL SURVEYS

The Bureau of Land Management is the only agency authorized to conduct surveys fixing township and section corners in accordance with the rectangular system of surveys. These surveys form the basis of all legal descriptions of land and are necessary in establishing the location for rights-of-way, and in fact establishing ownership or control of land. Accurate locations are necessary in all planning and land classification programs. They form the basis for the mapping of basic resources and the condition and character of the land. Accurate locations in the construction phases of the Upper Colorado

River storage project will be necessary in the acquisition of rights-of-way and the determination of adverse claims on the lands affected. They will be needed in the laying out of farm units and settlements as the participating projects enter into the over-all program.

In the Upper Colorado River basin there is a gross area of some 73,577,000 acres of land divided cadastrally as follows:

Unsurveyed	16,377,000 acres	
Old surveys	32,752,000 "	
Iron post surveys	24,448,000 "	considered as sufficiently surveyed for most purposes.

With some exceptions the unsurveyed areas should all eventually be resurveyed cadastrally so that the land can all carry a legal description and known area. The exceptions are the very rough canyon areas and such permanent reservations as national parks and monuments where no land transactions normally take place.

The old surveys, those executed before 1910, should all be resurveyed with perhaps the following exceptions:

1. Highly developed suburban areas that have been adequately shown on local plats of record.
2. Incorporated areas, such as cities and towns.
3. Areas within permanent reservations such as national parks and monuments, where cadastral resurveys may be limited to boundary surveys and to surveys within the reservations sufficient to define private property limits.
4. Areas of sold private ownership in counties that have kept good local records of survey monuments and of cadastral activities of local county surveyors and other local engineers.

The cost estimates as shown in the accompanying program are based on a survey of 75 percent of the unsurveyed acreage, and a resurvey of 60 percent of the area of "old surveys."

RESOURCE MANAGEMENT, PROTECTION AND REHABILITATION

A. Grazing.

The Taylor Grazing Act of June 28, 1934 authorizes the Secretary of the Interior to establish grazing districts upon the public domain. The primary objectives of this act are:

1. To stop injury to the public grazing lands by preventing overgrazing and soil deterioration.

2. To provide for their orderly use, improvement and development.

3. To stabilize the livestock industry dependent upon the public range.

Almost all the public domain in the Upper Colorado River basin is located within eighteen established grazing districts. These districts and the acreage in each are listed below.

Grazing District	Acres	Grazing District	Acres
Colorado #1	1,727,000	Utah #5	2,170,000
" #2	336,000	" #6	2,466,000
" #3	1,143,000	" #7	3,127,000
" #4	1,045,000	" #8	1,782,000
" #6	858,000	" #9	1,708,000
" #7	1,336,000	" #11	2,528,000
Total	6,445,000	Total	13,781,000
Wyoming #3	909,000	Arizona #1	156,000
" #4	4,400,000		
" #5	1,212,000	New Mexico #1	872,000
Total	6,521,000	" #7	867,000
		Total	1,739,000

The total of lands within grazing districts: 28,642,000 acres.

Livestock raising is the principal agricultural pursuit in the Colorado River basin. Because of the vastness of the public domain it constitutes an important part of the livestock operations. This industry, being one of the important pursuits, exercises a strong influence on the prosperity of the Basin as a whole. The Bureau of Land Management is charged with the responsibility for the stabilization of this industry in so far as use of the public domain is concerned, and at the same time conserving and developing the resources on the public land.

The Taylor Grazing Act authorizes the Secretary of the Interior to issue, or cause to be issued, permits to graze livestock on the grazing district lands, to bona fide residents, settlers and other livestock owners. Permits have been issued to approximately 4700 operators to graze a total of approximately 2,237,000 head of livestock. The number of permittees and numbers of livestock permitted to use the grazing district land is shown in the table on the following page.

State and District	Number of permittees	Number of Permitted Livestock Cattle	Horses	Sheep	Goats	Total
Colorado #1	163	22,000	560	127,000		149,560
" #2	252	48,000	940	41,000		69,940
" #3	396	36,000	930	117,000		153,930
" #4	269	17,000	90	90,000	50	107,140
" #6	88	4,000	190	92,000		96,190
" #7	555	38,000	620	80,000		118,620
Total	1,723	145,000	3,330	547,000	50	695,380
Utah #5	308	20,000	310	49,000		69,310
" #6	103	14,000	190	77,000		91,190
" #7	438	23,000	920	88,000		111,920
" #8	220	12,000	350	177,000		189,350
" #9	92	7,000	80	109,000		116,080
" #11	364	19,000	560	28,000		47,560
Total	1,525	95,000	2,410	528,000		625,410
Wyoming #3	79	6,000	300	115,000		121,300
" #4	307	27,800	1,200	430,000		459,000
" #5	174	44,200	2,500	105,000		151,700
Total	560	78,000	4,000	650,000		732,000
Arizona #1	13	2,000				2,000
Total	13	2,000				2,000
New Mexico #1	392	8,000	900	90,000	3,000	101,900
" #7	564	3,600	3,200	66,000	8,000	80,800
Total	956	11,600	4,100	156,000	11,000	182,700
Grand Total	4,777	331,600	13,840	1,881,000	11,050	2,237,490

Prior to the passage of the Taylor Grazing Act, there was no control of the use made of these lands and each individual had to be the first one on the lands with his livestock in order to protect his interests. Range livestock operations were conducted with a minimum of overhead. Before the days of reclamation a minimum of cultivated forage crops were produced. The livestock were permitted to graze upon the public range during all seasons of the year, including those seasons when grazing on the range is most destructive. As a result of this condition, when grazing districts were first established a large part of the public domain was in a seriously depleted condition.

BUREAU OF LAND MANAGEMENT

Under the Taylor Grazing Act and the rules and regulations promulgated thereunder, the public domain lands are administered in accordance with accepted range management practices giving appropriate consideration to the effect of such administration on the local economy. Because of the character of the land, proper management requires the application of many scientific principles. The grazing district lands, for the most part, are located in the most arid portions of the basin and there exists a delicate balance between soil conditions, natural vegetative cover and climate. Under these circumstances natural balances are easily disturbed.

In management of the public ranges four cardinal principles of range management are recognized and applied. These are (1) proper numbers of livestock, (2) proper seasons of use, (3) proper distribution of use, and (4) proper class of livestock. The number of livestock using the range is controlled by the permits issued. Proper seasonal use is accomplished by the construction of drift fences, stock water holes and other range improvements designed to control or encourage livestock to use the range according to the season for which it has been classified. This practice is, however, influenced to a large degree by the production of cultivated forage on privately owned land to supplement range forage during periods when the range cannot be properly grazed. The distribution of livestock on the range is accomplished through construction and use of range improvements and such accepted range practices as herding and salting. Class of livestock grazed is ideally governed by the dominant type of range forage. It is often necessary, however, to modify this practice according to the prevailing type of agriculture on the irrigated lands.

The livestock industry is dependent upon the production of hay and other feed crops for their livestock when range forage is not available or cannot be properly used. Experience has also shown that ample supplies are the best insurance against drought and severe winters. A stable livestock economy is dependent upon a proper balance between cultivated feed crops produced and the available seasonal forage production on the range. The increased hay production resulting from the development of the Upper Colorado River basin will complement the range forage and ultimately result in increased total livestock production. However, careful planning will be required to avoid an adverse effect. Most of the ranges are already fully stocked and if the additional production resulting from new irrigation merely permits the introduction of more livestock into the Basin without adjustments in seasons of use and feeding periods, there will be increased pressure for more stock on the range for the same periods of time. By advance planning for readjustments in management plans, the increased production on irrigated lands can relieve the pressure on overgrazed ranges while they are being rehabilitated to produce more forage than they now produce.

BUREAU OF LAND MANAGEMENT

The interrelationship between production on privately owned or controlled land is further emphasized by the methods of adjudicating grazing privileges under the Taylor Grazing Act and the Federal Range Code. These rules and regulations under the Act provide that preference will be given to livestock owners who own or control land or water used in connection with the public range. With the exception of the grazing districts in Arizona and New Mexico, grazing privileges in the Upper Colorado River basin have been apportioned to livestock operators on the basis of ownership or control of land. It is required that the operator possess sufficient land to feed his livestock for a given period of time. The development of additional feed on irrigated land will make it necessary to make substantial adjustments in range apportionments and livestock operations in the Basin.

The Upper Colorado River storage project will result in some ranch properties with grazing privileges attached to them being inundated by water. The public land on which some operators have grazing privileges will be cultivated or otherwise needed in connection with the project. In those cases where the operators lose their base properties they should have an opportunity to transfer their grazing privileges to other properties which can be used in connection with the public range. A study of the operations of those whose range allotments are needed in connection with the project should be made with a view to rounding out their operations on other lands or by use of new feed supplies resulting from increased irrigation. This will involve a revision in management plans for the units involved as well as the processing of appropriate transfers of grazing privileges.

The estimated funds required to make the necessary studies, reapportionment and transfer of grazing privileges as a result of the expected expansion of the livestock industry, are reflected in the attached program schedule under "Adjustment in Range Management Plans and Apportionment of Grazing Privileges".

B. Soil and Moisture Conservation.

The President's Reorganization Plan No. 4 of April 11, 1940 transferred the responsibility for soil and moisture conservation operations on lands administered by the Department of the Interior from the Secretary of Agriculture to the Secretary of the Interior. Special funds are made available to the Department of the Interior and to the Bureau of Land Management to carry out this responsibility.

Bureau of Land Management conservation operations are organized by project areas. The project area is a unit of land on which rehabilitation and conservation practices are essential for the prevention of critical soil erosion and the wastage of water resources. These are areas that have been seriously impaired by wind or water erosion,

or both, as a result of improper use by man or his animals, drought, or damage by fire or floods to such an extent that they require remedial action. Bureau of Land Management activities are carried out on the public lands within approved soil and moisture project areas. Lands in other ownership, the rehabilitation of which would vitally affect adjacent or nearby public domain lands, also may be included in the soil and moisture conservation program through cooperative agreement and contributed funds.

First priority for soil and moisture conservation operations is given to those lands described as being in the severe-to-critical stage of man-induced erosion, where such erosion is endangering other lands or public facilities such as irrigation projects. Soil and moisture operations may be carried out on lands in less serious condition when their treatment is necessary for success on lands in the first category. Funds made available for soil and moisture conservation are used to carry out proven erosion control practices designed to protect the soil and hold it in place. These practices include reseeding, construction of small detention and check dams, contour furrowing, water spreading devices, and construction of livestock control fences and stock-water development to insure uniform utilization of native forage.

It is estimated that between 50 and 60 percent of the lands under the administration of the Bureau of Land Management in the Upper Colorado River basin is in severe to critical erosion condition, and it is known that the public domain lands are the principal contributors of sediment to the Colorado River system. This erosion is attributed to a combination of features, including topography, geology, soil, climate, and land use. The situation in the Colorado River basin with respect to the first four features mentioned naturally results in an unusually high rate of erosion. The public lands in the Upper Colorado River basin are, however, characterized by broad alluvial filled tributary valleys. These are the most productive of the public lands. Because they were originally the best grazing lands, they were the most seriously misused. This misuse is responsible in a great measure for the present extensive gully system which is characteristic of the most critical erosion in the basin. These gullied valleys are the greatest potential source of sediment for transportation into the main system of the Colorado River. Because of the more favorable soil conditions, they are also the areas on which effective treatment has been demonstrated. To obtain optimum benefit of the flow of the Colorado River and to provide maximum benefit for existing and contemplated structures on the river, as well as to prevent excessive destruction of the watershed itself, a conservation program for erosion abatement is essential.

While a number of conservation measures and erosion control measures have proved effective on a small scale and under given conditions, there is urgent need for extensive studies in erosion control and sediment abatement on a larger scale and over a greater sample of geologic formations, soils, and climatic conditions. For the protection of the Upper Colorado River storage project and participating projects, these studies should be undertaken at an early date.

C. Timber and Woodland Management

The public domain lands have not been considered important for their production of forest and woodland resources. However, these areas do support unknown quantities of saw timber and extensive stands of pinon and juniper. Prior to the passage of the Act of July 31, 1947 (6 Stat. 681, 43 U.S.C. sec. 1185), commonly called Public Law 291, there was no authority for the orderly management and sale of timber and woodland products from the public lands, except under wartime emergency provisions. Disposal of these products was by free-use permits for woodland materials such as posts, poles and cordwood for use by local residents. The Secretary of the Interior is now authorized to sell woodland products and a small amount of money has been appropriated for the administration of this law. The amount appropriated does not allow the inventorying of the woodland areas and providing for supervision to abate trespass and to develop orderly management plans. The total volume of forest and woodland products on the public lands is not known. In addition to the value of the resource for the product itself in the economy of the basin, the protection from erosion afforded by the forest and woodland cover is an important factor. This is especially true because many of the forest and woodland types are found on steep slopes.

The anticipated increase in rural population resulting from the Colorado River storage project and participating projects will create an additional demand for forest and woodland materials. These will consist largely of posts and poles for fencing and other farm improvements. The attached budget schedule for the Upper Colorado River basin reflects the cost of forest and woodland inventories. These will consist of detailed inventories to determine total volume and allowable cut in areas where it is anticipated that the demand will be greatest.

D. Fire Control

In connection with its public land management and protection program, the Bureau of Land Management is charged with the responsibility of fire protection. Investments in conservation must be protected from forest and range fires which can cause damages requiring years to correct.

Fire is historically one of the destructive agents of western watersheds and has been the cause of serious erosion problems in some areas. With expected improvement of the Colorado River watersheds through more intensive management, it is reasonable to assume that the fire hazard will become more acute, requiring a greater investment in fire presuppression and suppression.

E. Wildlife (Game Management)

The public domain lands provide part of the yearlong habitat of the big game population of the Basin. Because the lands administered by the Bureau of Land Management are located in medium and lower elevations, they provide a substantial part of the winter grazing for game animals. While the Fish and Wildlife Service and the State Game Commissions are the agencies responsible for the technical game management programs, the land management agencies must consider the use of the land made by game and provide for their use in their management plans, as well as resolve conflicts resulting from competition between wildlife and domestic livestock for range forage. Experience has shown that failure to recognize this dual use has resulted in serious erosion problems. Increases in population in the Basin will create a need for recreational opportunities, including hunting and fishing.

PROPOSED PROGRAM
BUREAU OF LAND MANAGEMENT
UPPER COLORADO RIVER BASIN

Program Element or Function	Funds Required by Fiscal Year						Total Estimated cost 6-yr.	Funds Required after F. Y.
	1952	1953	1954	1955	1956	1957	1952-1957	1957
Adjustments in Range Management Plans and Apportionment of Grazing Privileges	10,000	65,000	65,000	65,000	65,000	65,000	335,000	65,000*
Cadastral Surveys	169,000	217,000	267,000	363,000	324,000	324,000	1,664,000	8,000,000**
Land Classification and Resources Inventories	130,000	195,000	243,000	244,000	244,000	244,000	1,300,000	1,500,000
Mineral Examination	8,000	10,000	10,000	8,000	8,000	8,000	52,000	----
Basic Land Records	10,000	15,000	15,000	10,000	10,000	----	60,000	----
Watershed & Sedimentation Studies	10,000	50,000	50,000	50,000	50,000	10,000	220,000	10,000*
Forest & Woodland Inventories	----	12,000	12,000	12,000	12,000	6,000	54,000	6,000
TOTAL	337,000	564,000	662,000	752,000	713,000	657,000	3,685,000	9,581,000

* Continuing

** Based on resurvey of 60% of old surveys (not iron posts) and 75% of unsurveyed area. By end of first six-year period it may be determined that the degree of coverage will need to be revised.

BUREAU OF MINES

INTRODUCTION

The Upper Colorado River Basin is entirely within Region IV of the Bureau of Mines, administered from Denver, Colorado. The only establishments of the Bureau of Mines within the basin are the Oil-Shale Demonstration Mine and Plant at Rifle, Colorado and a standby helium recovery plant at Shiprock, New Mexico. However, all of the personnel and facilities within the region and some outside are concerned with the many diverse mineral problems in the basin.

The development and conservation of the mineral resources of the Upper Colorado River Basin area within the States of Arizona, New Mexico, Colorado, Utah,and Wyoming are directly and indirectly affected by the development of the water resources and power. Without either, the other is impaired.

The national requirements for minerals are increasing while on the other hand the rate of discovery of many high-grade critical and essential minerals, including oil and gas, is on the decline. In order to keep abreast of the increasing national demand, it is necessary to provide measures to step up the rate of discovery of new reserves, reduce the cost of mining and handling ores by improvements in techniques, improve methods of recovery and separation, and develop better usage of the minerals and metals.

This nation produces and consumes roughly one half of the aggregate of all the mineral wealth in the world today. It is self sufficient in many minerals, particularly bituminous coal and lignite, anthracite, natural gas, phosphate rock and potash; and it is virtually self sufficient for the immediate future in a number of other metals such as copper, iron, molybdenum, and vanadium. Although many of these minerals in the eastern and central part of the United States are being rapidly depleted, large undeveloped or underdeveloped reserves exist in the Upper Colorado River Basin area.

The nation is dependent on the west for most of its copper, lead, zinc, gold, silver, vanadium, and petroleum. This area contributes a substantial part of these minerals and to a very great extent, the continued welfare of the nation depends upon maintaining a healthy mineral industry within the Upper Colorado River Basin area.

Table 1.-- Production of gold, silver, copper, lead, zinc, coal, petroleum, natural gas, and other minerals in the Upper Colorado River Basin area to 1948 (except uranium and vanadium) 1/

	Colorado	New Mexico	Utah	Wyoming	Total
Gold					
Ounces	8,905,764				8,905,764
Value	$198,397,513			a	$198,397,513
Silver					
Ounces	335,801,274				335,801,274
Value	$248,140,450			a	$248,140,450
Copper					
Pounds	331,242,771				331,242,771
Value	$41,418,335			a	$41,418,335
Lead					
Pounds	2,178,024,871				2,178,024,871
Value	$118,530,742			a	$118,530,742
Zinc					
Pounds	1,250,022,668				1,250,022,668
Value	$110,360,048				$110,360,048
Other metallic					
Value	$200,000,000b	a		a	$200,000,000b
Coal					
Tons	141,600,000	28,887,000	190,772,000	255,657,000	616,916,000
Value	$326,000,000	$70,953,000	$473,944,000	$474,315,000	$1,345,212,000
Petroleum					
Barrels	74,000,000	6,318,000		229,843,000	310,161,000
Value	$146,000,000	$7,982,000	a	$245,019,958	$399,002,000
Natural gas					
Million cu.ft.	64,500			133,745	198,245
Value	$2,980,000	a	a	$5,555,462	$8,535,462
Other nonmetallic					
Value	$10,000,000	$2,500,000		a	$12,500,000
Grand total value (approx.)	$1,401,827,000	$81,435,000	$473,944,000	$724,890,000	$2,682,097,000

1/Compiled from Geological Survey, "Mineral Resources", Bureau of Mines, "Minerals Yearbook", and statistics furnished by various Bureau of Mines Statistic and Economic offices.

a - None or minor

b - Includes 355,000,000 pounds of molybdenum valued at $159,000,000.

BUREAU OF MINES

MINERAL PRODUCTION AND EXTENT

The total production of minerals from the Upper Colorado River Basin, as shown in table 1, amounts to over two and one-half billion dollars based on the value of the raw material at the mine or well. Commercially the most important have been coal and petroleum. Coal represents over half the aggregate value of all minerals produced. Although the statistics of production are not available, the area is the principal source of uranium and vanadium in the nation. The principal reserves of molybdenum in the nation occur in the upper basin. Silver, gold, lead, and zinc are commercially important, and metals of minor interest include copper, manganese, bismuth, and antimony. Potash and magnesium, although undeveloped, occur in large partly proven reserves and phosphate rock is found in thick, medium-grade beds in Utah and Wyoming. The largest reserves of oil shale in the United States occur in northern Colorado and Utah and southern Wyoming within the basin. The search for petroleum and natural gas is being expanded rapidly and production continues to increase.

"Mineral Fuels and Other Hydrocarbons"

"Coal.--The upper basin contains enormous reserves of coal, mostly of bituminous and subbituminous grade. Reserves here are much larger than those in any other section of comparable size in the world and amount to approximately one-third of all of the coal deposits in the United States and one-sixth of those in the entire world. Some of this coal is below present mineable depths, but mineable reserves alone are nearly one-fourth of the nation's total deposits. Coal reserves within the upper basin are roughly estimated at 400 billion tons.

"The importance of these vast reserves is enhanced by the almost complete absence of any coal deposits in the states west of this region. The only exception of any consequence is the coal deposits of the State of Washington, but this coal is inferior in quality and more difficult to mine than the coals of the upper basin. Large quantities of coal from the upper basin are now shipped west, north, and sometimes east. These coals can be mined more cheaply than those in most other regions and may provide the basis for much of the future industrial development of the western part of the United States.

"Mine entries above ground level are possible for a large portion of the deposits. Thick beds, ranging from 8 feet to a maximum of 90 feet and virtually horizontal, can be mined with comparative ease.

"Bituminous coals from the upper basin are considered the highest quality bituminous coals on the western market. They are low in ash and moisture, extremely low in sulphur and highly volatile with a high heat

value. Largest coal mines in the upper basin are in the Rock Springs and Kemmerer districts in Wyoming, served by the Union Pacific Railroad, and near Price, Utah, on the Denver and Rio Grande Western Railroad. Most of the coal mined in the Colorado area is bituminous but some good grade anthracite is mined in Gunnison County.

"Coal production in the upper basin increased more than 50 percent in the period 1940-43. Part of the increase was in coking coals mined near Sunnyside, Utah, for new steel plants at Geneva, Utah, and Fontana, Calif. The new completely mechanized mine located near Sunnyside has a capacity to produce 8,000 tons of coking coal per day. Other important deposits of coking coal are located near Crested Butte, Durango, and Norwood, Colo. Coal in the Willow Creek area, Wyo., was found recently to be suitable for blending with other coal in the manufacture of metallurgical coke."

Coal production from the Upper Colorado River Basin has declined since World War II, due to extreme competition from petroleum and natural gas. However, it is indicated from fuel and population trends on the West Coast that large quantities of coal will be needed in the near future. The increasing use of coal in this market will be accelerated due to probable decline in petroleum and gas production. Already large gas lines are being extended from the upper basin to West Coast points.

Petroleum and natural gas.--Oil and gas have been discovered in over 40 widely separated fields in the upper basin. Most of the fields are located in northwest Colorado, southwest Colorado, and northwest New Mexico. It is reported that between 15 and 20 wells are in production in the newly discovered Ashley Valley field near Vernal, Utah.

The 1948 estimate of proven petroleum reserve in New Mexico, Colorado, and Wyoming was over one and one-half million barrels. The reserve strictly within the upper basin is not segregated. The estimated reserves of natural gas in New Mexico, Colorado, and Wyoming, mostly within the basin in millions of cubic feet, was about 9,000,000 at the end of 1948.

Oil shale.--The upper basin contains the largest deposits of oil shale in the United States. These beds of oil shale occur in Colorado, Utah, and southern Wyoming. Next to coal, they are potentially the most important mineral resource of the upper basin. The estimated oil-shale resources in northwestern Colorado, calculated from all the information obtained through 1950, indicate a total of nearly 500 billion barrels of oil in an average thickness of 500 feet of shale. The reserves in Utah and Wyoming probably are not as large as those in Colorado nor as readily mined.

"Bituminous sandstone and rare hydrocarbons.--Another oil-bearing material of great potential importance is bituminous sandstone. At the

present time it is being used as a road surfacing material. Large deposits are worked near Vernal and Sunnyside, Utah. The Vernal deposit contains about 2 billion tons averaging between 8 and 15 percent bitumen by weight, but most of it can be recovered only by underground mining. The deposit near Sunnyside is also very large; a sample of it averaged 11 percent bitumen by weight.

"The only known deposits of gilsonite, elaterite, wurtzilite, and ozocerite are in the upper basin. In normal times these materials are mined from veins and shipped to all parts of the world for use in the manufacture of roofing, insulating materials, and such articles as ink and switch handles.

"The gilsonite deposits occur mainly in the Uinta Basin in Utah."

Production of gilsonite in northeastern Utah amounted to 67,165 short tons valued at $1,746,228 in 1947 and 52,122 short tons valued at $1,390,713 in 1948.

"Reserves have been estimated at 25 million tons. The annual output of ozocerite and wurtzilite in Utah amounts to only a few hundred tons."

"This array of mineral fuels and carbonaceous materials is not approached by any region in any other part of the world. The extent to which these materials may provide the basis for future mining and mineral processing within the basin and in contiguous areas cannot be foretold definitely, but it is certain that their effect on future industrial development will be important."

Nonferrous Metals

The upper basin has contributed 8,900,000 ounces of gold, 336,000,000 ounces of silver, 1,000,000 tons of lead, 625,000 tons of zinc, and 165,000 tons of copper to the total mineral production of the nation. Virtually all of this production came from Colorado, primarily from the San Juan Region in San Juan and San Miguel Counties and from Eagle, Pitkin, and Summit Counties. Geologic conditions are favorable for increased production from these areas and other minor areas, providing sufficient incentive is offered.

Ferro-alloy Metals

The Climax Molybdenum district is the largest molybdenum district in the world and contains the largest single metal mine in Colorado. The district is situated on the Continental Divide in Lake County. The district has produced nearly 350,000,000 pounds of molybdenum, and the reserves are estimated to be 500,000,000 tons containing two billion pounds of

recoverable molybdenum. By-products produced from molybdenum treatment comprise tungsten, pyrite, tin, monazite, and topaz.

The Plateau area of Colorado, Utah, Arizona, and New Mexico is the principal source of uranium and vanadium in the United States. Deposits of manganese in the San Juan Mountains and in Eagle County within the upper basin and at Leadville, just outside the basin, may prove to be extremely important to the nation during an emergency. These ores are mixed with lead, zinc, and silver and are generally refractory and difficult to treat in order to separate the constituents. They represent one of the major metallurgical problems in the upper basin.

Nonmetallic Minerals

Although there has been no production, potentially phosphate rock and magnesium and potash salts constitute some of the most important mineral resources of the upper basin. Phosphate rock occurs in medium grade thick beds in the Phosphoria formation along the southern flank of the Uintah Mountains in Utah. Reports indicate the reserves are enormous. Recent exploration by the Bureau of Mines and Geological Survey near Thompson, Utah has proven the presence of extensive deposits of carnallite, a chemical combination of potassium chloride and magnesium chloride, and of other potash-bearing minerals. Associated beds of salt were found to be up to 2,000 feet thick.

When other more economically situated deposits approach exhaustion, these deposits of phosphate rock and potash will doubtless become important sources of mineral fertilizer.

DEVELOPMENT AND CONSERVATION PROGRAMS

The program of the Bureau of Mines in the Upper Colorado River Basin has as an objective the development and conservation of the mineral resources of the area and the promotion of accident prevention and health of the people working in the mineral industries. Development and conservation is being accomplished by providing means of (1) increasing the rate of discovery of new reserves; (2) reducing the cost of mining and handling ores by improvements in techniques; (3) improving methods of recovery and separation of minerals and metals; and (4) developing better usage of the minerals and metals.

Mineral Mining (Except Oil and Gas)

Mineral mining as used here includes the extension or discovery of mineral reserves, extraction of ores from the ground, and related problems. The functions of the Mining Division covering all problems involved in

mining broadly comprise (1) actual physical development to extend known reserves and discover new ones, (2) collecting information on mining practices at specific operations and actual research on specific mineral deposits, (3) studies of mining and related problems within natural mineral areas or other geographic subdivisions, (4) studies of mineral resources as they relate to other resources within basin areas, and (5) dissemination of the information through publication. All of these functions have as their primary purpose the conservation of mineral resources.

Mining development and research.--Mining development and research include the field of activity wherein (1) work is done to extend reserves of minerals in specific deposits or to discover new ones, and (2) research conducted on specific deposits, usually submarginal in grade, to develop methods of mining and better equipment. This field of endeavor has covered the entire Upper Colorado River Basin area and includes many of the metals and nonmetallics found in the area. A current list of pending development and research projects is maintained from which are selected those that best meet the national need as funds become available. Examinations and studies are being made constantly and the list revised to fit changing economic and technical conditions in the nation and the world at large. Examples of this field of activity are illustrated by the following description of several active and proposed projects:

Coal mining methods and reduction of losses.--The purpose of this project is to conduct research in mining thick beds of coal to increase the extraction as a conservation measure. The over-all extraction of coal in thick beds ranges from 30 to 70 percent. The loss represents a national extravagance that may prove very costly for future generations.

Ferrous metals and alloys.--Large reserves of mixed manganese-lead-zinc ores and refractory manganese silicate are known to exist at Leadville, Gilman, and Silverton, Colorado. Nationally, manganese, as well as lead and zinc, are in critically short supply. The higher grade manganese, low in lead and zinc content, has been virtually exhausted, and many of the mines are largely caved and inaccessible. Most of the remaining manganese is marginal or submarginal in grade according to present standards, intimately mixed with lead and zinc, or otherwise refractory, and the metals cannot be separated economically by known methods. The solution of the problems relating to mining and metallurgical recovery would make available an important source of these scarce metals.

Nonferrous metals.--The Upper Colorado River Basin area has been the source of a considerable quantity of many of the most important nonferrous metals, particularly copper, lead, zinc, and many minor metals recovered as by-products from smelter and refining plants. These metals are on the critical list, and most of the mining development and research in the area is devoted to problems relating to increasing reserves by extension of known deposits and discovery of new ones.

BUREUA OF MINES

It is proposed to conduct experimental mining on narrow lead-zinc-bearing veins that are found in many places throughout the area. The veins contain large quantities of metal that are uneconomic to mine under present standards. The object of this project is to investigate and develop less costly and more efficient methods of mining, to test equipment to determine that which is more adaptable, and establish better practices that will reduce the cost of mining. Successful solution of the problems involved in mining narrow veins will increase the known reserves materially.

Projects designed purely to develop or extend reserves of minerals by examination, comprising mapping and sampling, diamond drilling, trenching, and underground excavation, are selected each year from a list of requests for work from owners of prospects, examinations by Bureau of Mines engineers, and recommendations from the Geological Survey. These projects cover the entire area of the upper basin.

The gravels in many of the streams that have their source in the mountains on the western slope of the Rocky Mountains in Colorado contain gold. Considerable placer mining has been done along these streams. The extent of these gold-bearing gravels and the gold content has never been determined. Before any large reservoirs are established that might cover these potentially valuable gravels, a thorough job of sampling and testing should be done to determine the metal content. Other valuable minerals may also be found.

Consideration should be given to providing sluice boxes to trap gold and other heavy valuable minerals on all Government projects or contracts where aggregates from stream beds are to be mined for construction purposes.

Nonmetallic minerals.--Development and research on nonmetallic mineral deposits are becoming increasingly important as new uses for the minerals are discovered. Steadily increasing demand for these minerals has prompted the Bureau of Mines to expand investigations.

Pegmatite dikes are scattered through the large granitic mountain masses in Colorado and New Mexico within the upper basin. These are the source of many uncommon nonmetallics, such as beryl, mica, lithium minerals, columbite-tantalite, feldspar, and numerous undifferentiated rare earth minerals.

Usually the dikes are mined in a haphazard and expensive manner by individuals or small groups to recover one or two of the constituent minerals and the remainder is wasted. This results in operations that are uneconomic and the minerals are not available when emergency needs arise. The prices therefore are too high for general use in special processes and industries where they would improve the process or product.

Several projects are being considered to determine the extent and mineral content of selected individual dikes, conduct research to determine the most economical methods of mining the commercial minerals, conduct tests at the mine and in laboratories to effect separation and recovery of the various constituents, and make economic studies to determine the best combined methods of obtaining production from the dikes in case of economic need and emergencies.

Mineral research unclassified.--Mineral surveys are conducted on a district or county basis. These surveys comprise studies of past and present activities in the production of minerals, methods and practices employed in mining, treatment, and related mineral industry activities. The information is compiled, analyzed, and published.

Mineral mining methods and cost surveys are made on individual privately operated mines throughout the upper basin. These studies are published and made available to the mining industry. They have proven helpful to the industry in solving many operational problems.

The proposed Park Tunnel, to drain the mines in the Park City district, Utah, is outside the Upper Colorado River Basin, however, it is presented here because any water drained from the mining areas probably will have to be renewed through water exchange which ultimately will have to be supplied from the upper basin.

The great need for additional water in the Salt Lake Valley has prompted studies of the justification and feasibility of a tunnel through the Wasatch Range, serving the purposes of water diversion from the Provo River and drainage of the Park City and Alta mines. The water diversion aspects of the tunnel now appear to be more economically accomplished by other methods; however, the need for draining the mines is still a virtual necessity to enable the mines to operate over any long period of time.

The important mines are within a 3-mile radius of Park City. Production has been continuous since the first mineral discovery in 1868, and for the years 1870 to 1948, inclusive, the recorded value of recovered gold, silver, copper, lead, and zinc has been $385,000,000. A group of smaller mines surrounding Alta have produced over $34,000,000 in gold, silver, copper, lead, and zinc.

Water has been the greatest difficulty in developing the Park City mines. As mining has continued to greater depth, tunnels have been driven at progressively lower levels to drain mine areas. At present, the Ontario No. 2 is the lowest drainage tunnel in the Park City area and it drains about 6,000 gallons per minute from one section of the area. Mines in this section have been developed 450 feet below the tunnel, but mining below the tunnel has been impossible for some years because of the excessive cost of pumping that would be involved. The Spiro Tunnel drains another

section of the area and normally collects about 6,000 gallons a minute of which 4,500 gallons per minute is pumped from 700 feet below tunnel level. Mines in this latter section have recently been closed and expect to request some Government subsidy to permit them to cover the extra cost of pumping.

It has been estimated that the proposed Park Tunnel, 1,000 feet lower than present water level, would make accessible for mining 6,500,000 tons of ore above the tunnel and 3,250,000 tons below the proposed tunnel, having an aggregate value of half a billion dollars.

Without the water diversion features originally considered, it is tentatively estimated that the tunnel can be driven for 20 to 25 million dollars and completed in 7 to 10 years.

Metallurgical Research

Today, virtually no mineral resources other than some fuels go directly from the mine to the ultimate consumer. Our mineral economy is based largely upon the economic effort required to convert naturally occurring deposits of raw materials into beneficiated and purified products which will fit into established use patterns. Although billions of tons of important metals such as manganese, aluminum, and iron exist in the United States, we are greatly concerned about shortages, because it is not now feasible, economically and technologically, to convert many of these very low-grade and often refractory resources to materials which are suitable for the production of ferromanganese alloys, aluminum ingots, or pig iron. It is this field of translating mineral resources into terms of useful products that is the concern of the Metallurgical Division.

The metallurgists by employing advances in the sciences and improvements in technology are finding it feasible to beneficiate, smelt and refine consecutively lower grade and more refractory ores, thereby increasing our mineral wealth in terms of utility. The metallurgist also devises means of recovering and producing new materials demanded by advances in related fields for rare elements such as thallium, zirconium, beryllium, and uranium. Conversely, metallurgical research is concerned with providing new materials from minerals which occur in abundance but have been neglected. For example, research by the Bureau of Mines recently demonstrated that titanium, one of the most plentiful elements in the earth's crust, can be fabricated as a metal in ductile form having the strength of steel and only one-half the weight, and military demands already far exceed production even at prices higher than $10 per pound.

Ferrous metals and alloys.--The proposed metallurgical program in ferrous metals and alloys as it may apply to the Upper Colorado River Basin

includes investigation of the recovery of titanium, vanadium and iron from titaniferous magnetite; ferrograde manganese from low-grade ores; silico-manganese from rhodonite ore; and manganese, zinc, and lead by amalgam metallurgy from low-grade complex ores. A few typical proposed investigations are more fully described in the succeeding paragraphs.

Domestic manganese ores in most instances are too low in grade to be used directly by the steel industry and require beneficiation for the production of ferrograde manganese. At present, the steel industry is dependent upon foreign sources of manganese; and in the case of a global crisis, it is improbable that shipping lanes can be maintained to meet the needs of a wartime economy. It is proposed to develop processes to treat the low-grade ores in the region and to obtain engineering data from pilot-plant operations. The mineral beneficiation and processing by hydrometallurgical and electro-metallurgical means would be investigated to demonstrate efficient methods of converting low-grade ore to products acceptable to the ferroalloy industries.

Deposits of rhodonite, a silicate of manganese, and rhodonitic-type ores are a potential source of manganese for the steel industry. The deposits in Colorado represent a considerable tonnage and have been ignored previously because the ores contain excess silica and are unadaptable to the production of ferromanganese. It is reported that in 1949 the steel industry was ready to use as much as 230,000 tons per year of silicomanganese in lieu of ferromanganese and ferrosilicon. It is proposed to investigate the production of silicomanganese from rhodonite.

The I. G. Farbenindustrie of Germany has developed a new metallurgical process called "amalgam metallurgy" based on the cyclic use of mercury as a reagent. Among the accomplishments claimed for this process are (1) production of high-purity zinc, manganese, and other metals from impure electrolytes; (2) direct electrolytic production of alloys of virtually any desired composition; (3) electrolytic production of powdered metals and alloys; and (4) ability to produce 99.999 per cent zinc, lead, and other metals from low-grade and complex ores. The process may be applicable to many deposits of low-grade ores in the region such as the manganese-zinc-lead-silver ores of the Leadville and Gilman districts, Colorado. It is proposed to study all available information concerning the process, to conduct investigations on laboratory scale, and if the results are sufficiently encouraging, to try it in a pilot plant treating typical ores.

Pyrometallurgical research proposes to study the development of processes for treating strategic domestic ores such as those of chromium and manganese by pyrometallurgy and by electrometallurgy. This study will develop more economical methods for producing ferroalloys acceptable for use in industry. It will also develop methods for the simultaneous recovery of silver, lead and zinc from low-grade manganese ores. Technologic studies, already complete, indicate the feasibility of developing and improving such

processes and the final step in producing metal always involves a process in pyrometallurgy, electrometallurgy or by electrolysis.

The production of manganese by electrodeposition from chloride electrolytes prepared from low-grade domestic ores appears to be economically feasible. Laboratory work has indicated that leaching low-grade manganese ores with hydrochloric acid and ammonium chloride followed by electrolytic deposition of manganese can be adapted to commercial production. This project proposes to study the factors involved in converting the present laboratory process into a commercial process by erecting and operating a production pilot plant that will produce 1,000 pounds of pure manganese metal per day.

Nonferrous metals.--Copper, lead, zinc, antimony, gold, and silver deposits represent the chief nonferrous mineral resources and the suggested metallurgical program includes investigations directed toward the solution of major problems confronting industry for the more efficient utilization of these resources. In addition to the more common nonferrous metals, the area is the only important source of uranium and vanadium. Programs for these particular metals are given as are descriptions of investigations dealing with the production of such rare metals and elements as hafnium, gallium, germanium, selenium, tellurium, beryllium, titanium, and zirconium by special processes. The following paragraphs discuss the significance and scope of a few typical suggested metallurgical investigations.

Uranium.--The area encompasses virtually all the known producers of uranium ore in the United States. The uranium occurs in many types of minerals which are in general low grade. As the mining and processing of uranium ores become more declassified and are taken over more by industry, the need for technologic data will be critical. It is proposed to investigate processes for beneficiating low-grade ores and for the treatment of many off-grade types to permit the widest production of this important element. The information sought would be that which could be generally disseminated without jeopardizing national security.

Many major problems face the western mineral industry in meeting the demands for ever-increasing amounts of lead and zinc. These problems can be attributed to the exhaustion of high-grade ores, with the consequence that lower grade and more complex ores must be worked, and to the increased cost of obtaining the metals from more remote and smaller deposits. In seeking a technologic solution of these problems, it is proposed to make a comprehensive study in two directions as follows:

Unitized small smelting plants - The success of large integrated smelters in acting as custom buyers for ore has to a large extent discouraged investigation into the feasibility of building and operating small-scale smelters suitable for treating complex lead ores. However, existing smelters were originally located close to large mining districts, which

have now been exhausted; and with the increased cost of hauling ore to these smelters many remotely located complex ore deposits cannot now be profitably exploited. One possible solution is to devise a simplified smelting process using a minimum of equipment to make the capital cost low and so unitized as to be readily moved to a new location.

Volatilization processes - Another attack on the same problem of treating complex ores, particularly partially oxidized ores of lead and zinc, is the possibility of developing a volatilization process for treatment of this type of ore. The Waelz process, as employed on very low-grade and complex ores in European countries, has not been adequately tried in the United States; and it is proposed to determine what modifications of the basic process are needed to make it applicable to treating domestic ores.

Nonmetallic minerals.--The nonmetallic mineral program of the area is headed by the vital problem of investigation, the utilization of the low-grade western phosphate ores by mineral beneficiation, furnace treatment, and chemical processing. The program also includes the beneficiation and preparation of clays for irrigation ditch linings, catalysts, and various other uses; the recovery of economic and rare, strategic minerals from pegmatite dikes; and the evaluation of the rare earth content of placers, dikes, and disseminated deposits in the area.

The reserves of western phosphate rock are tremendous, but most of the phosphate beds are not high in grade. Utilization of these low-grade deposits will be essential in the future economy of the area. Before any large-scale use can be made of the phosphate ore and shales, a technology must be developed for the low-cost beneficiation, and furnace or chemical treatment, of the low-grade ores and shales that are minable by large-scale and inexpensive methods. Laboratory and small pilot-scale studies would comprise the major part of the initial proposed mineral beneficiation work, and the emphasis would be on the use of low-cost gravity, flotation, and dry methods to produce acceptable feed material for the more expensive chemical or furnace treatment. The pioneering studies would be supplemented by larger scale demonstration units to further prove the processes and provide data using commercial-size equipment. It is further proposed to study the feasibility of treating the beneficiated phosphate material by various alternative chemical and furnace methods to recover superphosphates, elemental phosphorus, by-product vanadium, and defluorinated products.

In the conservation of water resources, the prevention of seepage losses from water ponds and irrigation ditches is becoming increasingly important. As much as 25 percent of the irrigation water in secondary and tertiary canals and ditches may be lost by seepage. A small amount of a swelling-type bentonite mulched into the porous and sandy soil forms an impervious coating that reduces water seepage and thereby conserves the limited supply for useful irrigation purposes. A number of bentonitic clay

deposits are known to occur in the river system areas. Although some of the Wyoming and South Dakota bentonites are high-grade swelling types, the Colorado and Utah deposits are generally of the non-swelling type that would require physical beneficiation and chemical processing to increase their gelling and swelling properties to make them useful as a lining material. It is proposed that a laboratory investigation be initiated to study the beneficiation and base exchange methods for converting the readily available non-swelling type bentonites to useful and low-cost swelling type bentonite. A further objective of the work would be the preparation of satisfactory swelling-type bentonite and activated bentonite for well-drilling muds and oil clarification to be used in oil fields and refineries.

Important areas of pegmatite dikes in the area contain economic minerals such as feldspar, mica, zircon, quartz, and lithium minerals. They also contain rare and strategic minerals such as beryl, columbium, hafnium, and thallium. Quartz, feldspar, and zircon are used in large quantities for the production of ceramics, glass, and refractories, while mica, lithium minerals, beryl, columbium and tantalum, hafnium, and thallium are all important strategically and occur rarely in the United States. It is proposed to make laboratory and pilot-plant studies of methods for the production of economic minerals from the vast dike systems.

The major portion of the metallurgical work would consist of laboratory and small pilot-plant studies in mineral beneficiation aimed at the production ofthe principal minerals such as feldspar, mica, beryl, and lithium minerals. The project would also entail microscopic, chemical, and spectrographic studies of the rare elements and chemical extraction methods if this type of research were a logical sequence of the investigation.

Coal Utilization Investigations

Although coal production in the Upper Colorado River Basin is relatively low due to extreme competition of oil and natural gas, it is indicated from fuel and population trends in California that large quantities of coal will be needed in the relatively near future. At present, California uses relatively no coal but by 1955 it is indicated that about 10,000,000 tons will be required per year to supplement oil for generation of electric power. Each year thereafter more coal will be required because the demand for electric power in California more than doubles every ten years.

Raw coal from Utah costing $4.50 per ton at the mine can be shipped to California to compete with fuel oil at about $2.60 per barrel. Approximately the same will hold for coal from western Colorado with slight adjustments in freight rates. In 1949, the price of fuel oil rose to $2.45 per barrel, and it is indicated that by 1954 the average price of oil will be close to $2.60

If favorable coals in the Upper Colorado River Basin are distilled at low temperatures to make tar-oils and chars, it is feasible to recover up to 45 gallons of tar-oil per ton. The chars produced represent about 73 percent of the available heat in the raw coal but only about 63 percent of the weight. It is indicated that the cost of processing coal will be considerably less than the value of the tar-oils produced; therefore, the probable cost of char on a heating-value basis should be considerably less than the cost of raw coal delivered in California. If this can be proved by adequate research and development, a vast new industry and new markets for coal in the Upper Colorado River Basin will be created.

Although hydro-power development in the west will relieve the demand for electric power, it is pretty well proven that thermal power is necessary in some areas to sustain firm markets for hydro power. In a relatively few years, it will be necessary to install thermal power plants to supplement hydro power. Such plants should be designed to burn char for steam generation or for the gas turbine. The by-product tars produced would be the basis for new industries or raw materials for synthetic liquid-fuel plants.

Much research is needed to establish the technical and economic facts related to utilization of processed coal for power generation. The Coal Branch of Region IV has studied this problem in connection with utilization of Texas lignites. Similar studies on testing and appraisal of Upper Colorado River Basin coals should be conducted as a long-range problem to improve the western fuel picture. National fuel economy requires maximum efficiency in the use of fuel. This is especially true when considering shipments of large quantities of solid fuel to California where the freight cost exceeds the mining cost. By processing coal at the mine to remove moisture and inert constituents, the higher heating-value char can be shipped at less cost per heat unit and the savings in freight will pay a large part of the processing expense. The by-product tar-oils have value for chemical raw materials or for the manufacture of synthetic liquid fuel.

In planning the fuel economy of the Upper Colorado River Basin, multi-purpose use of coal should be considered as a conservation measure. Solid fuel should replace liquid fuel for generation of electric power because it is not desirable to burn oil for generation of power if coal can be supplied at equal cost. The same applies to natural gas.

The following discussion gives a striking example of the great potential possibilities in the use of processed coal for generation of electric power on the West Coast: The Pacific Gas and Electric Company is just about to complete the construction of two new large power plants at Moss Landing and at Contra Costa. These plants will cost over $100,000,000 and they are designed for use of oil, gas, or coal. Each plant will have a capacity of 300,000 KW. The PG&E expects to construct additional plants to keep up with the constantly increasing power demand.

Such a plant will require 718,000 tons per year of high-grade Utah coal of 12,500 Btu/lb. It will require 2.54 million barrels of fuel oil or 16.86 billion cubic feet of natural gas per year if these higher value fuels are used. Raw coal can be shipped from Utah to compete with oil when the price of oil is about $2.60 per barrel and this may occur in the relatively near future.

If coal is up-graded at the mine to make char and tar-oils, 1,000,000 tons of coal would be processed at the mine to produce 628,000 tons of char of 13,610 Btu/lb. The char thus formed will run the plant but the weight represents only 87.5 percent of the weight of raw coal needed. The freight saving will therefore be 12.5 percent or equal to 45 cents per ton of coal processed. The tar produced amounts to 45 million gallons or 1.07 million barrels per year. It is indicated that tar is worth about 11 cents per gallon and the tar value per ton of coal processed is $4.96. With the saving in freight of 45 cents per ton of coal, the potential values created to defray cost of processing amount to $5.41 per ton of raw coal. Since it is indicated that the cost of processing will be about $2.00 per ton, there is a substantial margin to reduce the cost of char delivered at the power plant to a point where it will compete with fuel oil.

The Coal Branch of Region IV, Bureau of Mines, has developed new processes for high-speed drying and carbonization of non-coking coals at low temperatures. Due to the high capacity of plants employing the new process, the investment cost is estimated to be about $1,000 per ton of daily capacity. The process is continuous and subject to automatic control. Coal is handled pneumatically in the fluidized state, there are no moving parts except a gas compressor, and the cost of operation should be less than $2.00 per ton of coal handled. The development of this process on a pilot-plant scale has been done in cooperation with the Texas Power and Light Company and it is indicated that processed lignite in Texas may soon compete with natural gas for power generation.

Research and development work on processing coals of the Upper Colorado River Basin is necessary to determine the technical and economic data for a more accurate appraisal of the possibilities of treating coal for shipment to California and for use in the basin in power plants supplementing hydro power.

Oil-Shale Development

Resources.--It is an accepted conclusion that liquid fuels play a major role in the economy of the United States and it is absolutely imperative that an adequate supply of such fuels be available at all times if we are to maintain our present standard of living. In the past, these liquid fuels have been produced solely from petroleum, and since petroleum is an exhaustible resource, it is mandatory that other sources of liquid fuels

be developed. Liquid fuels can be produced from such natural resources as coal and oil shale. In order that the United States will have an adequate supply of liquid fuels for an indefinite period of time, the second session of the 78th Congress passed the synthetic-liquid-fuels Act charging the Bureau of Mines with the responsibility of developing the necessary technology to insure that the nation would have a continuing supply at a low cost. In accordance with the provisions of this Act, the Bureau of Mines established and has in operation an oil-shale demonstration plant and mine near Rifle, Colorado, where work conducted to date indicates that liquid fuels can be produced from oil shale at costs not greatly exceeding the production of the same fuels from petroleum. However, in order to produce adequate supplies to augment our dwindling petroleum production at costs satisfactory to our economy, further research and development work are necessary and such research must continue as long as the natural resource is available so as to increase the quantities of liquid fuels, thus conserving the natural resource and reducing its cost so that it can be used more widely.

To date less than one third of the vast oil-shale deposits in Colorado have been proven or blocked out. As expenditure of nearly $1,000,000 over a period of six years would be necessary to block out completely a thousand square miles of probable commercial grade oil shale in northwestern Colorado. This work would include approximately 51 holes for a total length of about 91,000 feet.

Large deposits of Green River formation are known to exist in both Utah and Wyoming. However, little is known about the oil yield from the formation in these states. It is roughly estimated that with the drilling of 45 holes for a total of about 125,000 feet and the expenditure of about $1,440,000 the most important areas of these states could be located. It would take approximately six years to complete this preliminary program. Considerably more drilling would be necessary to determine accurately the extent of the areas located.

The term "oil shale" is a misnomer, as it is not a true shale but a marlstone and contains no free oil but an organic material which can be converted to liquid products.

The oil-shale project is composed of three distinct industrial phases; first, the rock must be mined and crushed; second, the solid organic products are converted to liquids; and third, the liquid product is converted to usable fuels. Since there was no technology available pertaining to these three phases of operation, it had to be developed by the Bureau of Mines. Although to date, as a result of experimentation and demonstration, the Bureau has been able to make marked progress in the development of this technology, a large amount of research work is yet to be done before economically feasible commercial projects can be established.

Mining.--During the period 1945 to 1950 the Oil-Shale Mining Branch has developed the equipment, method, and procedure for one means of exploiting the 70- to 90-foot-thick Mahogany Ledge of the Green River formation in western Colorado. Production rates of 148 tons per man shift underground labor have been demonstrated at a direct cost of 29.2 cents per ton.

It is estimated that a period of six years and an expenditure of about $3,200,000 are necessary to complete the present mining research program, design and fabrication of new and more efficient mechanized equipment, and to demonstrate their use in a unit of a large-scale operation. In addition, alternate methods of mining should be investigated and the mining of thinner sections containing greater values should be demonstrated and evaluated.

Mining research that must be completed includes improvements in operating procedure and lowering of operating supply costs for percussion drilling; rotary drilling research to determine optimum drilling characteristics of the oil-shale formation and the selection of suitable rotary bits; the completion of instrumented blasting research designed to lower the cost of explosives in both heading and bench rounds; investigation of alternate loading and transportation equipment should be done to lower the cost of these phases of the operation; exhaustive studies of accurate methods for determining the stresses in the mine structure must be continued and expanded; methods for ventilating large-scale commercial mine structures must be determined and demonstrated; and the possibility of mining by means of sonic disintegration should be fully investigated.

The present mine structure must be developed to demonstrate mining the 70-foot Mahogany Ledge on two levels employing both percussion and rotary-type drilling upon the completion of suitably designed mechanized equipment. A method for mining a 25-foot-thick bed yielding about 35 to 40 gallons per ton should be determined and studies of the mine structure stresses in such a mine should be made. Suitable equipment should be designed, fabricated, and demonstrated. Efficient mining cycles should be established.

Plant.--During the period 1949-50, the Oil-Shale Demonstration Branch has conducted research on an developed several retorting and refining techniques for the extraction of oil from shale and its subsequent conversion into usable liquid fuels. Numerous processes and specially developed equipment for using these processes have been developed, and from these additional information is steadily forthcoming from which better processes and types of equipment can be developed.

Retorting.--The only way known to date of converting solid organic material to liquid products is through the application of heat, and major

problems involved in the development of techniques and equipment are in reality a problem of heat transfer and material handling, and because of the complex organic material occurring in the oil shale the mechanisms of the chemical reactions for its conversion to oil must be understood in order that an adequate solution of the problem may be forthcoming. In order to solve these problems it requires the construction and operation of several stages of pilot-plant equipment to obtain the necessary thermodynamic and engineering information on which to base the design of a commercial plant.

Refining.--Since shale oil is a different chemical substance than petroleum, it cannot be converted to usable products using standard refining practices. The chemical complexity of shale oil is increased because of the presence of sulfur and nitrogen in combination with carbon and hydrogen. To solve the technical problems involved requires the construction and operation of numerous and various sizes of pieces of pilot-plant equipment. The devising of various processes and design, construction, and operation of equipment to reduce this process to practice and analyses of the data obtained therefrom are the bases of necessary chemical, thermodynamic, and engineering information necessary to produce commercial units capable of producing high-quality, low-cost products.

Plant location survey.--In addition to the development of necessary mining, retorting, and refining technology and drilling of core holes to prove the extent of the oil-shale deposits, it is also necessary to conduct location surveys for adequate sites upon which to establish an oil-shale industry. As previously stated, the Green River oil-shale reserves occur in abundance in northwestern Colorado, northeastern Utah, and southwestern Wyoming. In this particular area the terrain is extremely mountainous and cut with numerous river valleys. Because of the terrain and the extremely isolated areas, and in order to establish industries to utilize the resources, it is imperative that the area be thoroughly surveyed and adequate, detailed plot plants and topography maps be made so that the mines, plants, and refineries could be advantageously located with respect not only to each other, but with respect to availability of water, power, transportation facilities, and existing communities.

Petroleum and Natural Gas Research

In any planning or development program that might be undertaken relative to a river basin, the amount or the reserves of oil and gas should be known as well as the rate at which these reserves can be made available. It is necessary to know that in making these resources available, the oil and gas fields are operated so that the greatest recovery of these resources will be accomplished.

BUREAU OF MINES

An inventory of the physical plant in its branches of production, pipeline and refinery, as well as the requirements of energy and water and the utilization of manpower, all as of the present and projected into the future are requisites.

In the Upper Colorado River Basin there are undeveloped resources of materials that should be studied with the view toward the utilization of these natural resources in the economy of the area, materials such as tar, waxes, gilsonite, and the unusual natural gases.

Mineral Statistics and Economics

The Bureau of Mines collects production statistics of all the minerals produced in the United States. Each year these statistics and economic studies are published in the publication known as the Minerals Yearbook. This publication has a worldwide circulation and is regarded as the most authentic information available.

Within the area of the Upper Colorado River Basin, petroleum and gas statistics are collected in Los Angeles and gold, silver, lead, zinc, and copper statistics are collected in Denver and Salt Lake City. The present plan is to expand this collection of statistics at these offices to include all minerals. The importance of statistics of production cannot be over-estimated since it gives an index to the supply of critical minerals and metals available. A mining library is maintained in Denver and in Salt Lake City where the mining public, consulting engineers, and others interested in mining may obtain information readily.

Accident Prevention and Health in the Mining Industry

The Bureau of Mines was organized in 1910 following a series of disastrous coal-mine explosions which resulted in the death of hundreds of miners. The basic Act outlined, as one of the principal activities for the Bureau, studies to increase mine safety and the reduction of the accident rate in mines. Subsequent Acts of Congress greatly expanded the activities of the Bureau of Mines, and today the Bureau of Mines has an interest in all phases of mining.

The fatality accident rate in coal mines has been reduced from 5.63 killed per million tons of coal production in 1910 to 1.24 in 1949; there has been in the same period over 50 percent reduction in fatalities in non-coal mines on an exposure basis.

All coal mines in the United States are inspected from one to four times per year by the Federal coal-mine inspectors. Some very small mines

have not been inspected because of an insufficient number of inspectors. In the Upper Colorado River Basin area virtually every coal mine of whatever size has been inspected at least once every year. In addition to the inspection of coal mines, the inspectors are trained in the use of oxygen-breathing apparatus and are available in case of a disaster such as a coal mine explosion or a mine fire. There is seldom a year that the Bureau of Mines is not called upon to furnish trained personnel to assist in recovery work following a fire or a mine explosion.

The Accident Prevention Branch provides technological assistance in promoting mine safety in the metal and nonmetallic branches of the mineral industry. The work includes demonstrations of the hazards in handling and use of inflammable liquids such as gasoline, the use of Diesel engines underground and inspections of operating mines so that the known hazards may be pointed out to the operators. Employees in the mineral industry are given training in first aid to the injured and in the use and care of oxygen-breathing apparatus.

The work of both the Coal-Mine Inspection Branch and the Accident Prevention Branch includes much instruction of mine officials and employees through accident-prevention classes.

The Roof Control Branch studies the roof control methods practiced within the region, the use of timber and metal supports including various types of roof bolts, and the study of roof fall accidents which comprise at least 50 percent of the fatal accidents in the mineral industry. This branch is new to the Bureau of Mines, and considerable expansion is contemplated.

Mine ventilation, particularly in metal and nonmetallic mines, is generally inadequate. Most coal mines are ventilated in accordance with State laws. The Bureau of Mines furnishes technological advice to mine operators whereby the ventilation can be improved and brought to the standards set by the U. S. Public Health Service.

Studies are made of explosives practices in all types of mining. Explosives are one of the primary sources of serious and fatal accidents in mines. The work in testing explosives, and the study of fast-delay detonators, double priming, and fumes from explosives should be greatly expanded.

The mechanization in coal mines, particularly, and to a lesser degree in metal mines, has introduced new hazards in mines because of electricity used for power. The hazards of the use of electricity underground are not well known in many instances. This field of study should be augmented, and more information made available to the operator.

BUREAU OF MINES

Many millions of tons of coal are burned each year by fires which occur in the coal deposits in the western states. The Bureau of Mines is currently controlling fires in coal beds on the public domain and this should be continued until all known fires have been controlled. The cost of controlling these fires ranges from $200,000 to $350,000 per annum.

BUREAU OF INDIAN AFFAIRS

The whole Colorado River Great Basin is of special importance and significance to the Bureau of Indian Affairs. Within its broad boundaries live over one-fourth of the Indians of the United States totaling in numbers to approximately 101,600. Residing in that part of the Great Basin to be directly benefited by the Colorado River Storage Project of the Upper Basin are approximately 38,000 Indians. Eighty-four per cent of these Indians are Navajos, while members of the Ute and Apache tribes make up the balance. They are almost entirely dependent on the natural resources of their lands which are inadequate for their minimum needs. To them, as to their non-Indian neighbors, water is of vital importance. Historically, Indians within this arid region settled along the watercourses, particularly those of the Colorado River and its tributaries. It was inevitable that conflicts over the use of water with non-Indians should develop, and many such conflicts are still unresolved. With the settlement of the West, and the encroachment of non-Indians on lands which the Indians formerly used at will, reservations were established through treaty, executive order, and congressional action. Restricted to limited areas, and increasing in population, the Indians overgrazed their land and now face with non-Indians the problems of accelerated erosion, soil depletion and diminished resources.

Tribes within the Colorado River Great Basin have retained their aboriginal culture to a greater degree than tribes elsewhere in the United States. In many parts of the region the Indians have had only slight contact with modern technologies. Many Indians speak only their native tongue, and only a minority can read and write. There is a strong adherence to their traditional patterns of thought and behavior. The reluctance to accept modern technologies and concepts, the inability to read and speak English, and a resistance to leaving their reservations create serious problems in the economic development of the Indians of the region.

The basic responsibilities of the Bureau of Indian Affairs are twofold: To protect and develop Indian resources; and to help and encourage Indians in the slow and sometimes painful process of acculturation. The final goal is the integration of the Indians in the social, economic, and political pattern of American life. It is obvious that the work of the Bureau deviates widely from that of other Bureaus in the Department of the Interior.

Indians and Their Land

The Colorado River Basin is the pre-Columbian home of most Indians now living within its boundaries. They were not transplanted there from other parts of the country under the pressure of the westward movement of the white population. This has an important influence on their attitudes. They have strong emotional and cultural ties to their land, even though it is in many cases unproductive.

Within the Upper Colorado River Basin region Indian land holdings total approximately 11,000,000 acres located on reservations varying in size from the vast Navajo Reservation of over eight million acres within the "upper basin", while an almost equal acreage of this reservation is located within the adjacent "lower basin". The greatest part of this whole area is classified as open grazing land - most of which has a very low carrying capacity. There are 360,000 acres of Indian land susceptible of irrigation in the Upper Basin taking into account the full development of the projects now partially irrigated.

With some notable exceptions, the land base of the Indians is grossly inadequate, and even with proper development and use cannot support them at a minimum acceptable standard of living. They are, however, peculiarly dependent on the resources of their land. Most Indians are not equipped by education, experience or ambition to compete with non-Indians away from their reservations. Nor do they have the desire to leave the emotional security of their own environment and face insecurity and discrimination in the outside world, yet it is inevitable that many Indians must progressively seek their living away from their lands.

Indian Resource Problems

The Bureau of Indian Affairs is responsible for the protection, development, and conservation of all lands held in trust for the Indians. In the Upper Colorado River-Great Basin region these total over 11 million acres as already stated.

Certain problems faces by Indians in the development and use of their lands are common to all groups making a living from the soil of this arid region. In addition there are other problems peculiar to the Indian which intensify the difficulties of the Bureau in its administrative responsibilities.

Fundamental in consideration of Indian resource problems is the gross inadequacy of the land base, and the peculiar dependence of the Indians on their land for a livelihood. An increasing population has placed a progressively heavier burden on the land, and resulted in serious overuse of the grazing land especially. Its productivity has been drastically reduced, and in many areas accelerated erosion has taken place. The prevention of further deterioration of the soil, and the restoration of damaged areas are of major concern to the Bureau and to the entire region. The effect on Hoover Dam of the soil erosion on the Navajo Reservation has been widely publicized. There are other examples, less dramatic, throughout the region.

There are approximately 10.2 million acres of tribal land and 800,000 acres of trust allotted land in the Upper Colorado River Basin region. Both types of ownership present serious problems in the efficient use of the land. On many unallotted reservations the pattern of land-use is according to tribal custom without a formalized system of land assignment. Individuals and groups have certain historical land-use rights in areas which are informally recognized by other members of the tribe, but there is rarely any clear delimitation of the area. The Bureau and the Indians face the task of creating effective land-use codes, through which individuals and groups will have clearly established land-use rights to specific areas of land. In addition, governmental and tribal controls are needed to implement these codes and assure sound land-use practices.

Even more serious are the problems of proper land-use on trust allotments. The General Allotment Act provided for the allotment of small pieces of land to individual Indians, varying in size from 10 acres of irrigated land to 160 acres of grazing land. Under the law, trust allotments cannot be alienated, but on the death of an allottee are subject to the state inheritance laws. The result over the years has been a progressive subdivision of allotments which were often uneconomic units originally. Unless the numerous heirs to an allotment could agree among themselves, the individual holdings were too small to farm, and often fell into disuse. This process is continuing and threatens paralysis of some of the most valuable Indian land in the region.

Inadequate credit has been another obstacle to the full use of Indian lands for farming and stockraising. Indians are denied the usual sources of credit because of the trust status of their land, and their lack of property to use for security. Congress has never fully recognized the importance of this, and loan funds established through congressional action have not been large enough to meet all Indian needs. This in spite of an extraordinarily fine repayment record by Indians of the funds that have been made available.

The existing and potential projects of irrigable Indian land in the Upper Basin have all the problems of water rights, maintenance costs, drainage, water supply, and operation which are common to all irrigation projects. In addition the Indians have special problems inherent in the transition from subsistence farming to commercial farming and use of modern farming methods. The Bureau has the task of developing potential irrigation projects to meet the pressing needs of the Indians, safeguarding Indian water rights, and assisting Indians in learning new techniques of agriculture.

Irrigation

General

The complete utilization of all Indian basic resources must be brought about with the utmost speed in order to prevent a continuing drain upon the Federal Treasury for Indian support and to forestall the pauperization of a large part of the Indian population. And it is here that the importance of irrigation as a part of the economy of Indian administration becomes apparent.

Agricultural development by irrigation on most of the reservations in the arid and semi-arid regions constitutes the principal if not the sole means and opportunity by which the Indian may become self-supporting and make proper use of his lands. Also the continued and further development of Indian irrigation projects is essential to preserve the water rights pertinent to the reservations which have been established by treatises or other Federal enactment. This right becomes increasingly difficult to protect in the face of approaching full development of the general water resources of the country by other water users. At present the Indians are not prepared or equipped to develop their own water rights and it is the Government's duty to do so. Congress, facing the difficulties of Indian self-use of irrigated land and realizing the subsistence character of farming operations especially in its initial stages, in 1932 passed what is commonly known as the Leavitt Act (47 Stat. 564). This legislation provides in effect that no irrigation construction assessments shall be made against Indian lands so long as the title remains in Indian ownership. It further provides that the Secretary of the Interior may adjust or cancel any unpaid operation and maintenance assessments. Both unpaid construction and operation charges constitute first liens against the land, which will be recited in any patent or instrument issued for such lands.

It accordingly will be seen that the need for and the feasibility of irrigation projects for Indians should be determined by a somewhat different formula than is commonly used in determining the feasibility of irrigation projects for the more mobile white farmers. Economically, the Indian is confined to his reservation until the time comes when he has adjusted himself to the whites' "civilized competitive environment."

A large factor in the question of economic feasibility of Indian irrigation projects is whether it will tend to increase the chances of the Indians becoming self-supporting. Consequently the justification for Indian irrigation projects should to a large extent be measured by what it would cost in Federal gratuities if the irrigation projects were not constructed. Included in these gratuities are the many social and administrative costs created by the existence of a large substandard population.

Continuation of irrigation development for Indians together with the construction of works to serve such privately owned land as may be included in Indian irrigation projects should be continued by an organization directly under the control of the Indian Bureau. The success of an Indian irrigation project depends not only upon it being properly and economically constructed and operated but also upon the development of the Indian to the point where he will make use of the facilities provided. This is a human and social problem which necessarily must be worked out in company with the other elements essential to Indian advancement. The irrigation activities must dovetail into an integrated reservation program.

Indian Irrigation Projects in the Upper Basin Navajo Reservation - Potential and Existing

Shiprock Project - The resource development which would provide for the largest number of Navajo families is the proposed Shiprock-San Juan irrigation project. It is located south of Shiprock on the San Juan River in the northwest corner of New Mexico and comprises a large area of Navajo tribal land susceptible of irrigation from the San Juan River. The possibility of developing an irrigation project in this area has been under intermittent consideration for more than 50 years. Surveys have been made by one or more State Engineers of New Mexico, the Bureau of Indian Affairs, and the Bureau of Reclamation as well as by private persons. More recent studies of the Bureau of Indian Affairs in which the Bureau of Reclamation has substantially assisted have now reached the preliminary report stage. The final phases of this report together with any further extensive investigations must necessarily await the outcome of current negotiations endeavoring to reach an agreement covering allocation of the waters of the San Juan River and its tributaries taking into account the apportionments made to the Upper Basin States by the Upper Colorado River Compact.

The net area of the Shiprock Project pending the water supply determination and as assumed for preliminary report purposes is 114,000 acres, all of which could be irrigated by gravity facilities. A considerably larger gross acreage of 45,000 acres could be served by pumping with a maximum pump lift of 150 feet. In the event the Bureau of Reclamation's proposed South San Juan project is constructed as has been proposed, as much as 23,000 acres additional Indian land area could be included in that project.

Present project major structure plans are based upon participation in the power benefits and the use of the Navajo Dam and

Reservoir which comprises one of the main units of the Colorado River storage project, and has long been used as the storage site for the Shiprock project. This unit of the storage project as tentatively designed will have a capacity of over one million acre-feet.

At least a portion of the area of the Shiprock project would be competitive for the utilization of the San Juan River water supply with the potential South San Juan project as well as with the San Juan-Chama transmountain diversion project. These two latter proposed developments have been under investigation and study by the Bureau of Reclamation for several years. Obviously the size and cost of the several proposed projects in this region will depend upon final allocations of the available water supply. No determinations have as yet been made as to allocation of construction costs to power or to flood and silt control. The assumed 114,000 acre Shiprock project would provide economically sized farm units averaging 63 acres to 1800 families. Several times this number of non-farming families would eventually be supported as incidental to the extensive agricultural production which would surely result from a project of this magnitude.

Navajo Animas-La Plata (Potential Project)

Within the proposed extension of the Animas-La Plata project of the Bureau of Reclamation there is an area of 25,000 acres of Indian land on the Navajo Reservation which is susceptible of irrigation. This land lies in the Monument Rocks area north of Shiprock and would be served by extending the Animas-La Plata canal system. The Bureau of Reclamation is currently designing this project for a total area of 110,000 acres of which about 24,000 acres of non-Indian land is now under constructed works. The enlarged project involves the construction of nine reservoirs, a hydroelectric powerplant, together with a canal and distribution system.

Navajo Miscellaneous Irrigation Projects (Present and Potential)

The present irrigation development on the Navajo Reservation within the Upper Basin region consists of more than 40 small tracts varying in area from 20 to 4200 acres each. The aggregate area in these units now provided with irrigation facilities is approximately 15,000 acres of which about one-half is Class 1 and one-half Class 2 land of five classes of land surveyed.

These small irrigated tracts are scattered over the entire reservation and because of such dispersal fit in well with the livestock economy of the Indians. Expansion of a considerable number of these

units to their ultimate irrigable area estimated at some 25,000 acres in the aggregate should be given favorable consideration. The potential work involved in completing these small projects consists of extending and improving the canal and lateral systems, the development of some additional and supplemental storage capacity and the preparation of raw land for Indian use. Construction work is now under way on the more promising of these units and the preparation of detailed plans are sufficiently advanced so that the work can be continued. Further surveys will be made as required for the development of the remaining units which will be carefully selected. Based upon the estimated productive capacity of the present irrigated area it is believed to be sufficient for the support of 300 families. With the eventual completion of the more feasible units, it is estimated that an additional 200 families will be able to obtain self support by farming.

Uintah and Ouray (Existing and Potential Extensions) - Utah

There are 77,000 acres under irrigated works on the Uintah Reservation in Utah, supplied by water from the Uintah, Duchesne, Lake Fork and Whitewater Rivers; and 1250 acres with irrigation facilities on the Uncompahgre Reservation. It is planned to increase this to 22,000 acres.

A preliminary statement of the Bureau of Reclamation on the proposed Central Utah Project, which is currently under investigation, the initial phase development of which has been named as one of the principal participants in the Upper Colorado River account, states that this project "proposes to intercept water of the streams flowing down the southern slopes of the Uintah Mountains at sufficient elevation to flow by gravity into the Bonneville Basin.....Replacement of water thus diverted from the Uintah Basin would be accomplished under ultimate phase development by diverting water from the Flaming Gorge Reservoir on the Green River."

The Indian as well as the non-Indian landowners throughout the Uintah Basin are vitally interested in this project. The extent to which the proposed irrigation works will affect the water rights and present water supply of the Uintah Indian irrigation project is of utmost importance to the Indians and to the Bureau.

Jicarilla Reservation - New Mexico (Existing and Potential)

On the Jicarilla Reservation 800 acres are now being irrigated and plans contemplate increasing this area to 5,000 acres. The water supply is secured from La Jara and Dulce creeks. The present average

annual diversion is 4000 acre-feet and the average annual diversion requirement for the ultimate area is 25,000 acre-feet. The estimated cost of providing irrigation facilities for the additional area is $250,000.

Southern Ute and Ute Mountain Reservations - Colorado (Existing and Potential)

Within the Upper Colorado River Basin in Colorado are two Indian projects, the Pine River and the Mancos River. The combined present irrigable area amounts to 8600 acres and plans contemplate expanding this area to 20,350 acres. The present average annual diversion is 43,000 acre-feet and the average annual diversion requirement for the ultimate area is estimated at 72,750 acre-feet. The two projects are described as follows:

Southern Ute - Pine River - On the Southern Ute Reservation 8400 acres are now supplied with irrigation facilities of which 2400 acres are in non-Indian ownership, and plans contemplate expanding the area to 19,850 acres of which 3700 will be non-Indian. The water supply is secured from Pine River and tributary creeks. The present average annual diversion is 42,000 acre-feet and the average annual diversion requirement for the ultimate irrigable area is estimated at 70,250 acre-feet. The tentative estimated cost to provide irrigation facilities fro the additional area is $860,000.

Ute Mountain - Mancos River - On the Ute Mountain Reservation there are 200 acres being irrigated and plans contemplate expanding the area to 500 acres. The water supply is secured from Mancos Creek. The present average annual diversion is 1000 acre-feet and the average annual diversion requirement for the ultimate irrigable area is estimated at 2500 acre-feet.

Soil and Moisture Conservation

The approximately 10,700,000 acres of Indian land in the Upper Basin of the Colorado contribute the highest amount of sediment of any other equal area in the Basin. They constitute about 1/7 of the area but contribute between 1/5 and 1/4 of the sediment. Two-thirds of the Indian lands are severely or critically eroded. Erosion and sediment removal are due to a combination of climate, geology, soil, topography, vegetative cover and land use. Indian lands have been seriously depleted by wind and water erosion caused by improper use by men and livestock together with drought, fires and torrential rains.

The Indian Bureau has successfully demonstrated that this damage can be economically checked and lands restored by water diversion, water-spreading, revegetation, streambank protection and other related soil and moisture conservation practices. Control of erosion and restoration of Indian land resources are an integral part of the Bureau programs and policies of resource management. Indian resources in the Basin are seriously inadequate for the present population. Land losses from erosion must be checked more rapidly than means to date have made possible or the Indians' extremely low standard of living will be further reduced and accelerated erosion will add progressively increasing amounts of sediment to the already excessive loads into the streams, reservoirs and other downstream developments.

There are about 3,500,000 acres of forest and woodland on Indian reservations in the Upper Basin of the Colorado with an estimated stand in excess of 6 billion feet of timber. It has been estimated that within this area on about 500,000 acres of this land there are 2 billion board feet of commercial saw timber. The area and volume of timber are based on ocular estimates and not on actual forest surveys. These forest resources are important to the Indians for fuel, posts, poles and other forest products and as a source of income from sales of timber. It is the established policy of the Bureau of Indian Affairs to manage the forest resources in accordance with the principles of sustained yield. In the circumstances, a comprehensive survey of these resources should be made to obtain essential data for dependable management plans. Such a survey is now being made of the forest resources on the Navajo reservation where a tribal sawmill enterprise is being conducted. Conservative development of the timber on the Jicarilla and Consolidated Ute Reservations has been primarily through sales of timber to non-Indians.

The Indian forest and woodlands in this region have been protected from fire to the extent that limited funds have been available for that purpose. The fire hazard in some parts of this area will probably increase because of the accumulation of forest litter and the dense growth of forest reproduction and other vegetation. This increase in fire hazard presents a serious problem which can be met only with increased funds for adequate organizations for fire prevention and control.

Considerable quantities of oil, gas, copper, uranium and other minerals are believed to exist on a number of Indian reservations in the region, particularly in the Navajo-Hopi area where there have been productive oil and gas leases for many years. An obstacle to further exploitation of these resources is the lack of adequate surveys and studies. On the Hopi Reservation explorations by the major oil companies indicate the possibilities of highly productive oil deposits, and efforts have been made by them to obrain leases from the tribe. So far, however, these efforts

have been unsuccessful because there is no central body among the Hopis authorized to act for the entire tribe. It should be stated with respect to the Hopi Reservation that most if not all of its area as usually designated is located just south of the dividing line between the Upper and Lower Colorado River Basins and accordingly cannot be considered an Upper Basin reservation.

Bureau Programs

The future programs of the Bureau of Indian Affairs in the Upper Colorado River Basin as elsewhere are designed to achieve the economic and social rehabilitation of the Indians through the provision of "adequate education, health, and other public service facilities, the development of physical and other subsistence resources on the reservation, and assistance in obtaining stable employment or occupation off the reservation."

Long-range programs are contemplated for all reservations, and are now being prepared by Indian Bureau officials and Indian groups. The basic objectives of these programs as stated by the Commissioner of Indian Affairs are: "The establishment of various tribes or groups of Indians on an economic level comparable to other citizens of the area; their integration into the social, economic, and political life of the Nation; and the termination at the appropriate future time, of Federal supervision and control special to Indians."

The Navajo program deals with the rehabilitation of a large and comparatively primitive Indian group, living on an unallotted reservation to which they have strong cultural ties, but which is totally inadequate to meet their minimum needs. The program includes vigorous measures to develop and protect the land through soil and water conservation, irrigation projects, and range improvement. Additional emphasis is placed on the exploitation of minerals, and expansion of the present timber operations.

The funds available to the Bureau of Indian Affairs through annual appropriations have been insufficient to implement long-range plans such as the Navajo. Special authorization was requested for this purpose in a bill "To promote the rehabilitation of the Navajo and Hopi Tribes of Indians and the better utilization of the resources of the Navajo and Hopi Indian Reservations, and for other purposes." This bill was passed by both the Senate and the House in the 81st Congress but was vetoed by the President. An amended version was passed in the second session of the 81st Congress in April 1950.

The future work of the Bureau is of course dependent on the availability of funds, and the acceptance by the Congress of the principle that it is sound economy to spend the money necessary to rehabilitate Indian groups to the point that they can become independent of special Federal services. Within the Upper Colorado River Basin region, the development of Indian resources is closely related to the overall planning of the area. It must be coordinated with the work of other Bureaus of the Department of the Interior, and all other branches of the Government in this field.

Interior--Duplicating Section, Washington, D. C.

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UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
WASHINGTON, D. C.

A PRELIMINARY REPORT ON FISH AND WILDLIFE RESOURCES IN RELATION TO THE COLORADO RIVER STORAGE PROJECT AND PARTICIPATING PROJECTS

Sponsoring Agency:	Bureau of Reclamation, Region 4
Source of Engineering Data:	Bureau of Reclamation, Region 4
Location:	Wyoming, Utah, Colorado, New Mexico, Arizona
Field Investigations:	1950
Report Prepared:	January 1951

Field Work and Report by
Office of River Basin Studies
Albuquerque, New Mexico

A PRELIMINARY REPORT
ON THE COLORADO RIVER STORAGE PROJECT
AND PARTICIPATING PROJECTS
Utah, Wyoming, Colorado, New Mexico, and Arizona

1. Pursuant to Public Law 732, 79th Congress, 2nd Session, and a Memorandum of Agreement between the Fish and Wildlife Service, Region 2, and the Bureau of Reclamation, Region 4, dated December 5, 1949, there is furnished below a preliminary report which outlines the effect that the Colorado River Storage Project and its participating projects would have on fish and wildlife resources. It reflects the opinions of the Fish and Wildlife Service and the fish and game conservation agencies of the States of Utah, Colorado, Wyoming, Arizona, and New Mexico. It is planned that detailed fish and wildlife investigations and reports on individual features of the project will be prepared as promptly as possible. The objective of such investigations is to prevent damage to fish and wildlife resources which would otherwise occur as a result of the project.

2. Biological investigations, prerequisite to preparation of a preliminary evaluation report on the effect of the proposed developments on fish and wildlife resources, were begun in 1949, but due to the immensity of the individual projects, the complexity of the habitat, the shortage of time and personnel available, complicated by the inaccessibility of the areas, the information obtained was necessarily meager.

3. This preliminary report reviews available data covering the proposed Colorado River Storage Project and the participating projects, and describes some of the ways that fish and wildlife resources would be affected by the projects. It points to the developments that would be most detrimental, and suggests some modifications that would mitigate damages to the fish and wildlife resources.

4. The Colorado River Storage Project would be a multi-purpose project. Some of the principal objectives are briefly described below, but not necessarily in their order of importance. One objective would be the storage and regulation of Colorado River flows sufficient to meet aggregate downstream requirements and permit upstream utilization with a reasonable assurance of adequacy during years of low stream flow.

5. Another objective would be to generate electrical power by utilizing the flows released to meet downstream commitments. Sale of this power should, according to present plans, provide sufficient funds to repay construction costs and provide an interest component which could be used for a third objective, that of assisting irrigation developments in the basin which could not otherwise meet their repayment costs in the allotted period. These would be "Participating Projects".

6. The fourth objective would be to provide water for irrigation. Some water would be delivered to presently irrigated lands in trade for established water-rights so that diversions could be made at higher elevations for use in other basins, especially in connection with the Central Utah Project development where trans-mountain diversion would be made to the Bonneville Basin and possibly in the Gunnison-Arkansas Project area where diversion would be made to the Arkansas Basin.

7. The fifth and sixth objectives would be to retain silt and to level out flash flood peaks.

8. These objectives would be accomplished by the eventual construction of the ten Colorado River Storage Project reservoirs and by other coordinated developments throughout the basin which would include construction of 15 or more participating projects. The proposed Colorado River Storage Project reservoirs and their purposes are shown in Table 1.

TABLE 1

Units of Colorado River Storage Project

Project and Reservoir	Name of River	Name of Dam	Principal Purposes to be Served
INITIAL			
Echo Park	Green	Echo Park	H, P, S
Flaming Gorge	Green	Ashley	I, H, P, S
Glen Canyon	Colorado	Glen Canyon	H, P, S
Navajo	San Juan	Navajo	I, H, P, S
Whitewater	Gunnison	Whitewater	I, H, P, S
ULTIMATE			
Cross Mountain	Yampa	Cross Mountain	H, P
Crystal	Gunnison	Crystal	P
Curecanti	Gunnison	Blue Mesa	I, H, P
Gray Canyon	Green	Gray Canyon	H, P, S
Split Mountain	Green	Split Mountain	P

Symbols used: I - Irrigation
H - Holdover storage for new irrigation
P - Power
S - Sediment retention

9. Initially, the participating projects would include: The Central Utah Project extending from Uinta Basin to the Bonneville Basin, Emery County Project in the San Rafael Basin, Seedskadee Project on Green River, La Barge Project on Green River, Eden Project on Big Sandy Creek, Lyman Project on Blacks Fork, all affecting the Green River drainage; Florida Project on Florida River, Pine River Project Extension on Pine River, the Hammond and Shiprock Indian projects on the San Juan River, all within the San Juan River drainage; Smith Fork Project on Smith Fork and Iron Creek, Paonia Project on Muddy Creek, all in the Gunnison River drainage; and the Silt Project in the Upper Colorado River drainage. Ultimately other projects will be undertaken as participating projects, all utilizing upper Colorado River waters.

10. The Colorado River Storage Project and participating projects would be concerned with the possible utilization of available stream flows throughout the entire 110,000 square mile upper Colorado River Basin. Stream flows available for upstream utilization would consist of the apportioned 7.5 million acre-feet annually of Colorado River water above Lee Ferry, Arizona, a point on the Colorado River just below the Utah line. By mutual compact the States of Wyoming, Utah, Colorado, New Mexico, and Arizona have established apportioned shares of this allotment for development and utilization in their respective states.

11. Pertinent engineering data relating to the Colorado River Storage Project are listed in Table 2.

12. The construction of dams and reservoirs as proposed in the Colorado River Storage Project and participating projects would, in general, destroy all present big game, upland game, fur animal, and waterfowl habitat in the reservoir areas. The ten Colorado River Storage Project reservoirs would alone inundate 700 miles of stream fisheries located within the 343,610 acres of reservoir area.

13. The fluctuating reservoirs would provide only poor type resting areas for ducks, unattractive shorelines for fur animals, and would expand the production of already abundant rough fish at the expense of all the abovementioned more desirable forms of wildlife.

14. Where flows of streams are periodically reduced by reservoir storage, or are otherwise diverted from the channel for irrigation or power production purposes, there would be an additional loss to the fishery and fur animals, and to a lesser extent waterfowl and upland game, unless sufficient and properly regulated flows are maintained.

15. Where sediment loads are reduced by deposition in the reservoirs and continuous favorable releases of cool water are achieved below the dams,

TABLE 2

COLORADO RIVER STORAGE PROJECT

(Data supplied or checked by Region 4, Bureau of Reclamation, November 1950)

					ELEVATIONS m.s.l.						CAPACITY				AREA				STREAM FLOWS	
Project Unit	River	Height of Dam (feet)	Main Streams Inundated (miles)	Drainage area above dam (sq. mi)	River Bed at Damsite (feet)	Water Surface at Max. Storage	Water Surface Av. Ann. Maximum	Water Surface Av. Ann. Minimum	Water Surface At Dead Storage	Approximate Av. Annual Fluctuations (feet) 1/	Maximum Reservoir Acre-feet	Average Annual Maximum (ac-ft)	Average Annual Minimum (ac-ft)	Dead Storage (ac-ft)	Maximum Surface Acres	Acres at Average Annual Maximum	Acres at Average Annual Minimum	Dead Storage Acres	Average Recorded Flow c.f.s. & a-f	Bureau Proposed Minimum c.f.s.
Cross Mountain	Yampa	295	Yampa 76	At Maybell 3410	5,800	6,090	6,067.6	6,053.7	5,963	13.9	5,200,000	4,116,300	3,528,200	1,000,000	52,200	44,100	39,700	17,500	At Maybell, Colo. 1,617 (1,180) 2/	705
Crystal	Gunnison	305	Gunnison 10	Below Gunnison Tunnel 3980	6,570	6,870	6,870 3/	6,870 3/	6,870	---	40,000	40,000 3/	40,000 3/	40,000 3/	560	560 3/	560 3/	560 3/	At Iola, Colorado 841 (1,323) 2/	805
Curecanti	Gunnison	475	Gunnison 30	At Iola, Colo. 2490	7,165	7,635	7,582.6	7,544.4	7,457	38.2	2,500,000	1,700,900	1,283,600	490,000	18,200	13,640	10,990	5,400	At Iola, Colorado 841 (1,142) 2/	670
Echo Park	Green	525	Green 63 Yampa 46	22,880 4/	5,050	5,570	5,530.8	5,521.2	5,362	9.6	6,460,000	4,772,800	4,445,200	1,000,000	42,800	36,250	35,000	9,800	4,712.3 4/ (3,288) 2/	2,160
Flaming Gorge	Green	440	Green 91	At Linwood, Utah 14,300	5,605	6,040	6,015.7	6,006.9	5,935	8.8	3,940,000	2,899,800	2,638,400	990,000	40,800	35,400	33,200	17,200	1,817 (1,636) 2/	1,020
Glen Canyon	Colorado	580	Colorado 186 San Juan 71	At Lees Ferry 107,900	3,135	3,710	3,667.5	3,647.2	3,490	20.3	27,800,000	20,134,500	17,640,500	6,000,000	153,000	133,900	122,000	40,900	At Lees Ferry 17,350 (13,763) 2/	12,200
Gray Canyon	Green	445	Green 53	At Green River, Utah 40,600	4,150	4,590	4,590	4,590	4,420	---	2,000,000	2,000,000	2,000,000	610,000	10,750	10,750	10,750	5,900	At Green River, Ut 6,740 (4,567) 2/	2,660
Navajo	San Juan	335	San Juan 33	At Farmington, New Mex. 6,580	5,625	6,050	6,037.3	5,988.2	5,875	49.1	1,200,000	1,079,000	699,300	150,000	10,800	10,000	7,230	2,275	At Farmington, N.M. 2,498 (1,260) 2/	690
Split Mountain	Green	245	Green 21	22,880	4,810	5,050	5,050	5,050	5,050	---	335,000	335,000 3/	335,000 3/	335,000 3/	4,250	4,250 3/	4,250 3/	4,250 3/	4,712.3 (3,228) 2/	2,130
Whitewater	Gunnison	255	Gunnison 35	7,780	4,635	4,880	4,880	4,842.7	4,760	37.3	880,000	880,000	565,000	410,000	10,250	10,250	7,220	2,550	At Grand Jct, Colo 2,761 (2,055) 2/	1,420

1/ Maximum average annual water elevations less minimum average annual water elevations.
2/ Modified average annual 1914-45 historical flow in 1,000 acre-foot units at damsites.
3/ Only daily or hourly luctuations. Entire capacity is considered inactive by the Bureau of Reclamation.
4/ Computed as for a point below Split Mountain damsite.

highly desirable sport fishing may be increased. Newly irrigated areas may favor production of pheasants, which would supplant the native upland-game populations, sometimes to the detriment of other species such as wild turkeys, sage hens, and deer.

16. The damage that would result to fish and wildlife by construction of the different projects throughout the Upper Colorado River Basin would vary markedly between those reservoirs in the mountains and those such as Glen Canyon Reservoir in the arid gorge of the Colorado. In the mountains, where much of the annual precipitation occurs as snow and there are frequent summer rains, vegetation is plentiful, soil fertile, streams generally clear and cold, and fish and wildlife abundant. Along the Green River in central Utah, and along the San Juan and Colorado rivers in southern Utah, rainfall during the growing season is insufficient to support cultivated crops, soils are dry or saline, palatable vegetative cover is sparse, and the rivers are heavily silt laden. Between these extremes are myriad combinations of slope, climate, and soil. Some combinations favor one type of game, some another, until in the relatively inaccessible canyon of the Colorado River only those animals which live in its muddy waters, or are able to subsist on the sparse vegetation among the cliffs, can maintain themselves.

17. Utilization of fish and wildlife resources produced within the upper basin varies principally with the accessibility of the area, attractiveness of the game, and distance from major centers of population. Split Mountain and Echo Park Reservoirs would lie partially within a National Monument where hunting is prohibited. All of the other project areas, except possibly Gray Canyon, are accessible to hunters, but access is not adequate to permit full utilization of the fish and wildlife populations. It is

expected that as roads are improved hunting and fishing pressure would increase with, however, much of the use continuing to come from persons living outside of the upper basin. In many instances the abundance of game animals has been the motivating factor in the opening of new roads. Some of the proposed reservoir sites are remote from centers of population, or may be so situated that they would compete with each other for use.

18. There are within the upper basin fewer than 25 communities having over 1,000 population. Only five communities have more than 5,000 of which Grand Junction, Colorado, (12,479) and Rock Springs, Wyoming, (9,827) are the largest. Total population within the 107,900 square mile basin is 286,450 with an average of 2.6 persons per square mile.

19. Highway distances from major cities outside the basin to the initial project reservoirs are shown in Table 3.

TABLE 3

		Distances to Reservoir Areas				
State and City	Population (1940 Census)	Echo Park 1/	Flaming Gorge	Cure-canti	Glen Canyon	Navajo
Colorado						
Denver	322,412	349	423	206	549	445
Pueblo	52,162	463	537	161	496	331
Colorado Springs	36,789	419	493	173	540	375
Utah						
Salt Lake City	149,934	182	256	438	405	459
Ogden	43,688	233	307	475	445	496
Provo	18,071	160	234	395	362	416
Arizona						
Phoenix	65,414	833	888	646	330	535
New Mexico						
Albuquerque	35,449	613	694	398	434	194
California						
Los Angeles	1,504,277	881	936	1,024	602	913

1/ Also Split Mt. and Cross Mt. Reservoirs

20. The proposed developments are so interrelated that monetary evaluation of the damages or benefits to fish and wildlife resources caused by any one of the project units would require careful analysis to determine its relationship to all the other projects.

21. In view of the magnitude of the changes that would occur to fish and wildlife habitat due to project construction, it is believed that separate evaluation reports should be prepared on each project as sufficient engineering data becomes available to make proper biological surveys and analyses. The Fish and Wildlife Service and the state fish and game departments would thus have an opportunity to make biological investigations and recommendations based on preliminary plans of the constructing agency. They would then be in a better position to fulfill the requirements of Public Law 732 for participation in the planning of the project in order to prevent loss of and damage to wildlife resources.

INDIVIDUAL UNITS AND THEIR ANTICIPATED EFFECT ON FISH AND WILDLIFE RESOURCES

INITIAL PHASE

22. The five reservoirs of the Colorado River Storage Project which are being considered for initial construction are Glen Canyon, Echo Park, Flaming Gorge, Navajo, and Whitewater.

Glen Canyon Unit:

23. The Glen Canyon Reservoir would be impounded by a dam, 580 feet in height, located in the narrow precipitous canyon of the Colorado River, fifteen miles above the Paria River and Lees Ferry in Arizona.

24. The reservoir would inundate 153,000 acres of poor quality wildlife habitat along the narrow gorge of the Colorado and San Juan Rivers where only meager vegetation persists. The reservoir would extend 186 miles up the Colorado River and 71 miles up the San Juan River and form a lake with but few points of access. The presence of the reservoir in Glen Canyon would make the entire area accessible by boats launched from immediately above the damsite or from either side of the reservoir where the present

Blanding to Hanksville road enters the reservoir area. At present the Colorado River in the reservoir area is accessible by automobile at but one place, Hite, Utah, and then only over a partially improved road not passable during rainy weather. Other access is by one-way boat trip down the Colorado River from Moab to Lee Ferry, down the San Juan River from Mexican Hat to Lee Ferry, or by pack trails through extremely rough terrain.

25. Fishery values in the Colorado and San Juan Rivers without-the-project based on present harvests would be insignificant. The reservoir would provide recreational potentialities, but because of its inaccessibility and the fact that there are other fishing areas nearer the important centers of population, it is expected that the reservoir fishing would not be fully utilized. Fishery value of the reservoir and the river below the dam would depend somewhat on the public recreation facilities provided and improved access.

26. The Colorado River below Glen Canyon Dam would become an improved fishery due to the proposed minimum release of at least 10,000 cubic feet per second of clear, cool water. Access to the river, however, would be limited to about a 25-mile section of the river near Lee Ferry.

27. Wildlife habitat in the reservoir area would be destroyed, but the reservoir would open the canyon area to travel so that some of the now isolated game populations above the reservoir could be better managed.

Echo Park and Flaming Gorge Units; considering Split Mountain and Cross Mountain Units:

28. Echo Park, Ashley (Flaming Gorge Reservoir), Cross Mountain, and Split Mountain Dams would impound a series of closely integrated reservoirs on the Green and Yampa Rivers near the point where Utah and Colorado meet along the Wyoming boundary. Only Echo Park and Flaming Gorge Reservoirs are being proposed for initial construction, but because the four reservoirs are so closely interrelated they are described together.

29. U. S. Highway 40 passes to the south of the Uinta Mountains about 25 miles from the three most southern reservoirs. U. S. Highway 30 crosses southern Wyoming north of the Uinta Mountains about three miles from the nearest point on the Flaming Gorge Reservoir. Access roads to the reservoir areas follow the rivers for only very short distances. These roads are open seasonally, generally graded but only occasionally graveled. The canyon areas are accessible only by boat down the rivers and from pack trails.

30. The four dams would form almost contiguous reservoirs on the Green and Yampa Rivers from Split Mountain above Jensen, Utah, to below Green River, Wyoming, on the Green River and below Craig, Colorado, on the Yampa River. The reservoirs would lie in the canyons and parks along the Green and Yampa Rivers where the rivers have cut through the Uinta Mountains of northeastern Utah, northwestern Colorado, and southern Wyoming.

31. Flaming Gorge Reservoir, the farthest upstream of the reservoirs in this group, would be impounded by the Ashley dam in the Red Canyon of Utah, but most of the 40,800-acre reservoir area would lie in Wyoming, where it would receive the turbid waters of the Green River.

32. The area to be irrigated from the Flaming Gorge or Echo Park Reservoirs would be on the south side of the Uinta Mountains where flows would be delivered from Flaming Gorge Reservoir through a tunnel or by pumping from Echo Park Reservoir. There would be some new irrigation areas developed in the Uinta Basin in connection with this reservoir development, but its principal purpose would be to trade assured flows to Uinta Basin areas for water originating in the mountains. The mountain flows could then be diverted by aqueduct to the Bonneville Basin for production of power and irrigation as part of the Central Utah Project.

33. Cross Mountain Dam, 295 feet in height, would be located in Cross Mountain Canyon; but the resultant 52,200-acre reservoir would inundate an open valley east of the mountains and 76 miles of the Yampa River.

34. Echo Park Dam, 525 feet in height, on the Green River would form a 42,800-acre reservoir 63 miles up the Green River through Lodore Canyon and Brown's Park to just below the Flaming Gorge damsite and for 46 miles up the Yampa to just below the Cross Mountain damsite.

35. Split Mountain Dam, 245 feet in height, would impound releases from Echo Park Reservoir in a 21-mile section of the Green River immediately below the Echo Park damsite. It would have only 4,250 surface acres at maximum water level with little seasonal fluctuation but considerable daily fluctuation.

36. Releases below Flaming Gorge and Cross Mountain Reservoirs would enter Echo Park Reservoir and flows released below Echo Park Dam would flow directly into the proposed Split Mountain Reservoir. Below Split Mountain Reservoir the Green River emerges from the mountains and flows in a southwesterly direction across the Uinta Basin to Ouray where it is joined by the White and Duchesne Rivers. This section of the Green River, from Split Mountain to Ouray, may have a decidedly improved fishery if constant releases from the reservoirs are provided.

37. There is some sport fishing on the Green and Yampa Rivers but the area is generally rough and inaccessible, the stream habitat is poor and, at present, the type of fish taken is not highly regarded for sport fishing. The reservoirs would probably produce more rough fish than could be taken for sport, so that the principal harvest would be by commercial fishing.

38. The proposed reservoirs would inundate small farming areas which have been established in the parks along the Green and Yampa Rivers. On the

steeper slopes above the farms, but within the reservoir areas, are ranges utilized by big game as well as livestock. Impounding of the reservoirs would seriously reduce the deer wintering areas, especially in Brown's Park, and it is doubtful if the remaining range could maintain the present deer herds.

39. Upland game, fur animals, and waterfowl would also be adversely affected by the project. The nesting sites of from 300 to 500 pairs of geese and of numerous ducks would be eliminated by the inundation of the "bottoms."

40. The possibility of establishing a migratory bird refuge on, or adjacent to the Echo Park Reservoir, provisions for the protection of big game by acquisition of lands about the reservoir, the enhancement of the fishing by maintaining suitable releases to the streams, and providing access to the fisheries so improved are being considered.

Whitewater Unit:

41. Whitewater Dam would be located on the Gunnison River approximately nine and one-half miles southeast of Grand Junction, Colorado. It would rise 255 feet above the stream bed to create the 10,250-acre Whitewater Reservoir that would extend 35 miles upstream to a point about four miles west of Delta.

42. This reservoir would not provide an outstanding sport fishery. A short stream section below the reservoir should be greatly improved by the proposed water releases. The reservoir would inundate about 10,000 acres of big-game, upland-game, and fur-animal habitat. Waterfowl would be benefited by the presence of the reservoir which would serve as a resting area during spring and fall migrations.

Navajo Unit:

43. The 10,800-acre Navajo Reservoir would be impounded by a dam 335 feet in height on the San Juan River above Blanco, New Mexico, and would inundate 33 miles of the San Juan River Canyon and portions of the Pine and Piedra Rivers.

44. The Bureau of Reclamation is also considering utilizing water from this reservoir for the irrigation of lands under the Shiprock, South San Juan, and possibly the Hammond Projects. Water would be carried by a common canal from the Navajo Reservoir to the project lands where smaller canals would divert the water to each of the units.

45. Construction of a dam and reservoir at the Navajo site should be considered in connection with the potential San Juan-Chama diversion to the Rio Grande Basin which could be very damaging to the Upper San Juan River fishery.

46. There is some fishing along the stream segments that would be affected by the reservoir. The meager fishery below the dam would not be maintained as the stream would be shut off periodically for storage; however, the reservoir might provide a better fishery than that destroyed by inundation. The effect on the fishery caused by diverted flows through the San Juan-Chama diversion would depend on the quantity and quality of residual flows in the San Juan Basin and by the type of habitat provided or destroyed in the Rio Grande Basin.

47. Plans are being made to carry out the necessary biological investigations to determine the most desirable operations for maintenance of this fishery. Minimum flows below dams and diversions are recommended especially below the Navajo Reservoir to protect the fishery in the San Juan River.

48. The reservoir area provides winter cover for deer, and wild turkey, and year-round habitat for small game animals. This wildlife habitat would be destroyed. However, there would be an increase of upland game in the areas which would be irrigated.

ULTIMATE PHASE

49. The ultimate development of the Colorado River Storage Project would consist of ten major reservoirs. Five of these reservoirs would be constructed in the initial phase as already described, and five others; namely, Cross Mountain, Crystal, Gray Canyon, Curecanti, and Split Mountain, would be constructed in the ultimate phase of the project. There may be two other reservoirs, not presently considered, which would have as their principal purposes the production of power and the retention of silt. These would be Dewey Reservoir on the Colorado River and Bluff Reservoir on the San Juan River.

Cross Mountain and Split Mountain:

50. Cross Mountain and Split Mountain Reservoirs were previously described with the Echo Park and Flaming Gorge Reservoirs because of their close relationship.

Crystal Reservoir:

51. Crystal Reservoir (560 surface acres) on the Gunnison River would serve mainly for power production, utilizing the flows released from Curecanti Reservoir. The reservoir would inundate ten miles of stream in the walled Black Canyon of the Gunnison River. Fishery values of the Gunnison River without-the-project are high, but values anticipated for the reservoir are low. The stream fishery below the reservoir as far as the Whitewater Reservoir should be good if the power releases are sufficiently constant.

Gray Canyon:

52. The 10,750-acre Gray Canyon Reservoir would be located in the extremely rough and inaccessible canyon of the Green River in Central Utah. It would be 445 feet deep at maximum water level and would extend 53 miles back into the canyon. The damsite would be located approximately 22 miles upstream

from the town of Green River, Utah, and would flood canyon areas, none of which are of agricultural value with the exception of the McPherson Ranch, comprising a small area near the mouth of Florence Creek.

53. Wildlife values in the area are low and the fishery within the reservoir area is almost non-existent. The reservoir should produce a meager fishery but its utilization for sport fishing would be low. Constant minimum flows below the dam should, however, improve the stream and provide several miles of fair trout stream.

Curecanti Unit:

54. The 18,200-acre Curecanti Reservoir would be impounded by the Blue Mesa Dam, 475 feet in height, located on the Gunnison River near Sapinero, Colorado.

55. The reservoir, inundating 30 miles of the Gunnison River, would be extremely damaging to both the fish and wildlife in the area. The reservoir would inundate sections of a stream and its tributaries which have been utilized extensively for recreational purposes. The present fishing use of the Gunnison River is high and is expected to become even higher in the future. Because of its scenic location, accessibility, abundance of recreational facilities, and consistent productiveness, this stream section is of exceptional value as a fishing stream.

56. Construction of the dam at Blue Mesa would destroy the valuable established fishery and in exchange would leave a fluctuating reservoir, much less attractive and unlikely to maintain a good trout fishery.

57. Flows of the Gunnison River below the proposed reservoir may have a more dependable late season flow than at present. The reservoir on the Gunnison may make possible water diversions from its head waters to the Arkansas Basin on the eastern slope of Colorado.

58. The Gunnison River Valley within the Curecanti Reservoir site is important as big-game and upland-game habitat. The reservoir would

inundate critically needed winter range for deer. This range is already over-utilized and further reduction in the amount of range available due to inundation would have an extremely harmful effect on the deer herd which is of great recreational value to the state. In view of the extremely harmful effects that construction will have on wildlife resources and lack of feasible means for mitigating these anticipated losses, this Service recommends that the investigation of alternate sites be continued, in cooperation with the State Game and Fish Commission and the Fish and Wildlife Service in order that wildlife losses may be kept to a minimum.

59. There would be some beneficial utilization of the reservoir by waterfowl and fur animals but the over-all annual loss to wildlife would be great.

PARTICIPATING PROJECTS

60. The separate projects which are presently proposed for initial participation in the Colorado River Storage Project plan are described briefly in the following paragraphs. The Fish and Wildlife Service, together with the appropriate state game and fish agencies, will prepare separate reports on each of these projects. One of the detailed reports (Paonia) has been completed, preliminary reports have been prepared on nine, and field work has been initiated on several others.

Eden Project, Wyoming:

61. The Eden Project, consisting of a 40,000 acre-foot reservoir on Big Sandy Creek and an irrigation system, 35 miles north of Rock Springs, Wyoming, will provide water for 11,000 acres of new land to be irrigated and a supplemental supply for 9,000 acres of land now under irrigation.

62. The project was approved for construction by President Roosevelt in September 1940, but construction was stopped by order of the War Production Board in December 1942. Completion was re-authorized by the Act of June 28, 1949.

63. Fishery values are low in the project area as the stream sections affected are often dewatered. Big Sandy Reservoir is not expected to provide an important fishery. The Eden Project will eliminate valuable antelope and sage hen habitat; however, the new land to be brought under irrigation may provide habitat for pheasants.

Paonia Project, Colorado:

64. The Paonia Project, consisting of the 18,000 acre-foot Spring Creek Reservoir and appurtenant irrigation system, is designed to provide water for the irrigation of 2,210 acres of new lands, and supplemental water for 14,830 acres of land already under irrigation adjacent to the North Fork on the Gunnison River in Delta and Gunnison Counties, Colorado.

65. The proposed reservoir would not provide a valuable fishery; however, the stream fishery would be benefited under project conditions due to improved stream flows below the dam. Gains to upland game would occur principally as the result of the irrigation of new lands. There would also be small gains to both waterfowl and fur animals. The Paonia Project as proposed would result in minor benefits for both fish and wildlife resources.

66. In order to further improve habitat and utilization, it is recommended that waste areas and gullies in the irrigation area be planted and maintained for the propagation of wildlife, and that turnouts or parking areas be provided about the reservoir.

Central Utah Project:

67. The initial phase of the proposed Central Utah Project involves drainage areas of over 7,000 square miles. It would provide water for the irrigation of approximately 29,600 acres of new land and supplemental water for 163,960 acres of irrigated land in the Colorado and Bonneville Basins. In addition, 47,100 acre-feet of water would be available for municipal, industrial,

and related uses. Construction of four power plants would generate approximately 387 million kilowatt-hours of energy annually. Part of the power would be required for irrigation and drainage pumping.

68. The 37-mile Strawberry Aqueduct would intercept the flows of Rock Creek, Hades Creek, Wolf Creek, West Fork of the Duchesne River, Currant Creek, Layout Creek, and Water Hollow and convey them to the Strawberry Reservoir. Reservoirs to regulate inflow into the aqueduct would be constructed on Rock Creek, West Fork of the Duchesne River, and Currant Creek. Strawberry Reservoir would be enlarged by the construction of Soldier Creek Dam. An enlarged outlet-tunnel would permit releases of Strawberry Reservoir water for four power plants on the western slope of the Wasatch Mountains. Monks Hollow Reservoir, Utah Lake, and an enlarged Mona Reservoir in combination with the Wasatch Aqueduct, the Mona-Nephi, and the enlarged Elberta Canals would then distribute the water to the irrigation areas of the Bonneville Basin. Exchange use of Provo River water as planned would require construction of three additional dams and related works, and include the diking and drainage of Provo Bay in Utah Lake.

69. Project works to provide water for replacement, expanded irrigation, and municipal use in the Uinta Basin would include dams on the Duchesne River, Strawberry River, and Brush Creek, with feeder canals into off-stream reservoirs from Lake Fork River and Ashley Creek.

70. As a result of project construction, excellent trout streams in the Uinta and Wasatch Mountains would be destroyed or severely damaged with only partial compensation to the sport fishery expected from the proposed reservoirs. Commercial fishing in Provo Bay would be cut off. A Federal refuge would be completely inundated and excellent waterfowl, upland-game, and fur-animal habitat destroyed. Critically needed big-game range would be further reduced.

71. The project would increase the abundance of rough fish and consequently improve the commercial fisheries. It would extend the habitat suitable for pheasants and some other upland-game species.

72. The Fish and Wildlife Service in cooperation with the Utah Fish and Game Commission have been making investigations to determine satisfactory means to replace the lost fish and game habitat "in kind" and to mitigate unavoidable losses. The difficulty of obtaining water to assure a stream fishery is emphasized, however, by the keen competition between municipal, industrial, and agricultural interests for the water to maintain themselves in this arid region. If the fisheries are to be maintained for posterity, expensive developments will be necessary to effectively manipulate the flows to maintain suitable fish habitat.

Emery County Project, Utah:

73. The Emery County Project, in the Colorado River Basin would impound the flows of Cottonwood Creek, in Lower Joes Valley Reservoir, for release to 3,630 acres of new land. The reservoir would provide a supplemental late season water supply to 20,450 acres of land now irrigated in the Huntington, Castle Dale, and Orangeville areas. The reservoir would provide sufficient storage to permit 900 acre-feet of water to be diverted to the Sanpete Project in the Bonneville Basin.

74. The fishery would be benefited by the project as the reservoir would provide better habitat than exists in Cottonwood Creek or the streams inundated. The elk and deer herds would be adversely affected because a sizeable portion of their critically needed winter range would be destroyed. The creation of habitat in the irrigation area would benefit upland game, especially pheasants, and to a lesser extent fur animals and waterfowl.

Florida Project, Colorado:

75. The Florida Project consisting of the 472-acre Lemon Reservoir on the Florida River and an enlarged and rehabilitated distribution system, would

provide supplemental irrigation water for 12,650 acres and a full supply for 6,300 acres of new lands in the Florida River Valley and on the Florida Mesa of southwestern Colorado.

76. Construction and operation of the project as proposed by the sponsor would enhance fish and wildlife resources. Deer habitat would be decreased but upland-game habitat would be improved. The estimated fur-animal values would increase slightly and no significant changes would occur to waterfowl. Constant releases, fish screens, and stream channel improvements are proposed to improve fishing conditions below the reservoir site.

Hammond Project, New Mexico:

77. The Hammond Project, on the San Juan River, would consist of a low diversion dam, an irrigation system, and a pumping unit with a water lift of approximately 50 feet. The project is designed to provide irrigation water for 3,670 acres of irrigable land near Bloomfield, New Mexico.

78. The waters of the San Juan River in the Hammond Project area provide only a poor fishery. They are heavily laden with silt and are warm and generally sluggish; however, Colorado squawfish, catfish, and a few brown trout are taken. Wildlife values in the project area are low. Sparse populations of scaled quail and Gambel's quail and good pheasant habitat are found near Farmington. Probably the only benefits which would accrue through project construction would be derived from increased upland-game habitat.

79. The Hammond Project may be included with the Shiprock and South San Juan Projects under one plan of development. Water would then be stored in the proposed Navajo Reservoir and a large canal would carry the water to the project area where it would be used for the irrigation of between 100,000 and 125,000 acres.

Lyman Project, Wyoming:

80. The Lyman Project would consist of a 460-acre off-stream reservoir at the Bridger Site on Willow Creek, and an irrigation system. The reservoir is designed to store the flows of Black's Fork and the West Fork of the Smith Fork River for supplemental irrigation of 40,600 acres of land near the town of Lyman, Wyoming.

81. The proposed project would be detrimental to the fish and wildlife resources of the area. The fishery resulting from construction of Bridger Reservoir would not compensate for the reduced fishery in stream segments affected by the project. Big-game and fur-animal habitat would be damaged; however, the reservoir would create some waterfowl resting habitat. Upland game would not be significantly affected.

Pine River Project Extension; Colorado and New Mexico:

82. The Pine River Project Extension is a feature of an ultimate project which would provide irrigation water for 69,000 acres of land in southwestern Colorado and northwestern New Mexico. At present, 33,200 acres are being irrigated with water assured by the Vallecito Reservoir. The proposed extension would consist of the enlargement and extension of twelve existing canals and ditches to irrigate an additional 18,650 acres of land.

83. The fishery of 42 miles of Pine River below Vallecito Reservoir would be affected by the project extension. The Fish and Wildlife Service has recommended water releases which would prevent damage to the fishery. Without these recommended releases, considerable damage would result. Rotary fish screens are being recommended for the headings of the four largest canals.

84. The project extension would cause a loss to big game through removal of the irrigation area from the present deer winter range. Upland game,

in general, would be benefited by the increase in irrigated land; however, sage hen habitat would be destroyed. The increase in the length and number of canals and ditches and the recommended stabilized and increased flows of the river would result in an increase in the populations of fur animals. Waterfowl nesting and feeding habitat would be increased somewhat.

Seedskadee Project, Wyoming:

85. The purpose of the proposed Seedskadee Project would be to irrigate 60,720 acres of sagebrush land on both sides of the Green River in Lincoln and Sweetwater Counties, Wyoming. A diversion dam would turn water from the Green River into a canal where a system of pumps and siphons would deliver it to the irrigation areas.

86. The mediocre fishery of the river extending 39 miles below the diversion would be adversely affected by depleted stream flows and occasional periods of no flow during the irrigation seasons. Fish screens are planned for the main canal near the headworks.

87. The project would cause a loss to big game through a reduction in range. There would be a loss in the sage hen population, but other species of upland game would probably increase. Fur-animal values would be slightly reduced. Some nesting and resting areas for waterfowl would be created.

La Barge Project, Wyoming:

88. The proposed La Barge Project would consist of a wing-type diversion dam and headworks on the Green River near Big Piney, Wyoming, and a 37-mile-long canal to provide water for irrigation of 8,436 acres of land along the west side of the river.

89. The La Barge Project alone would not adversely affect the fishery of the Green River, but would increase the damage that would be caused by the proposed Seedskadee Project. Irrigation of the sagebrush lands would

decrease the range of deer and antelope, causing some loss to these species, while the presence of the canal and farm fences would partially restrict the migration of elk through the area. Establishment of open lanes through the irrigation area with means of access for the migrating animals would reduce this restriction. Habitat for upland game with the exception of sage hens, would be increased and improved by the project. Fur animals would not be unfavorably affected by the La Barge Project alone; however, the adverse effects of the proposed Seedskadee Project would be increased by operation of the La Barge Project. Resting and nesting habitat for waterfowl would be slightly increased by the project.

Silt Project, Rifle Creek, Colorado:

90. The Silt Project, consisting of a 300-acre reservoir and a distribution system, is designed to irrigate 1,900 acres of new land and provide supplemental water to 5,400 acres already irrigated.

91. Fish and wildlife would be benefited as a result of the project. Big game would not be affected; however, habitat of upland game, fur animals, and waterfowl would be increased. The present low quality fishery of the seven miles of Rifle Creek below the dam would be improved if reservoir releases recommended by the Fish and Wildlife Service are made.

Smith Fork Project, Colorado:

92. The Smith Fork Project, consisting of a 420-acre reservoir, diversion canal, and irrigation system, would furnish supplemental water to 7,670 acres and a full supply to 2,130 acres of new land in the Cottonwood Creek and Smith Fork River areas of western Colorado.

93. Little change would occur in the fish and wildlife resources of the area as a result of the project. The fishery of Smith Fork would not be materially altered by the project because of present water priorities that must be maintained. The proposed impoundment would not provide a valuable

fishery because of the severe fluctuations and poor quality of the water. A small amount of mule deer winter habitat would be lost; however, upland game, especially pheasants, would be benefited by the food provided on the new land to be irrigated. Value of the project area would be slightly decreased for fur animals but increased somewhat for waterfowl.

SUGGESTIONS AND RECOMMENDATIONS

94. The foregoing statements were based upon information developed prior to November 1, 1950. Therefore, the Fish and Wildlife Service and the appropriate state fish and game departments should be advised of changes in project plans or methods of operation, as soon as they are anticipated rather than when they become final, so that the reports being prepared may include provisions to prevent damages to fish and wildlife.

95. The Fish and Wildlife Service, the fish and game departments of the states concerned, and the construction agency should confer in the early stages of project planning to formulate a general memorandum of understanding in order to establish a plan of procedure wherein fish and wildlife problems can be effectively presented.

96. The Fish and Wildlife Service, the state fish and game departments concerned, the Bureau of Reclamation, and the irrigation districts should enter into agreements, which would cover such assistance as the Bureau and the districts can reasonably and lawfully provide, making land within each of the districts accessible for public hunting and fishing and otherwise assuring that the maximum possible benefits are realized from the fish and wildlife resources.

97. Leases of Federal land in the project areas should stipulate the right of public access for the purpose of hunting, fishing, and other uncommercialized recreational purposes.

98. Management of the fish and wildlife resources in the project areas should be vested in the states concerned.

99. The Fish and Wildlife Service, the state fish and game departments, and other appropriate state agencies concerned should be given the opportunity to participate in the early planning of auxiliary features of the projects so that adequate road and trail systems and other management developments may be constructed to facilitate public access.

100. Title to all lands within the reservoirs and for an agreed upon distance from the perimeters at maximum pool elevations should be acquired in fee simple, or through the transfer of property, and be vested in the United States Government for the purpose of providing free public access.

101. No part of the reservoir areas or the acquired strips surrounding the reservoir areas should be leased for the exclusive benefit of any corporation, individual, or groups of individuals for any purpose which would prevent or interfere with the use of project areas for recreation, hunting, or sport fishing by the general public.

102. The Soil Conservation Service or other proper land management agency should be consulted concerning the employment of proper soil conservation practices on the project lands and their recommendations should be incorporated in the over-all plan for enhancing fish and wildlife habitat.

103. Releases from the reservoirs and diversions below dams should be accomplished by gradual operations of the gates to avoid sudden changes in the flows below the dams and rapid changes in reservoir pool levels.

104. Minimum flows to protect the fisheries in streams affected should be guaranteed as part of the operation of the proposed project.

105. Precautions should be taken during the period of construction to prevent excessive damages to fish and wildlife.

106. In making investigations and preparing detailed reports on the fish and wildlife aspects of individual units and participating projects, recommendations will be made to protect or enhance fish and wildlife values. Following are listed recommendations expected to apply to at least some of the projects.

a. All timber and heavy vegetation be cleared from specified areas of the reservoirs to permit efficient seining operations.

b. Adequate facilities be developed for the protection and management of migratory fishes affected by the project and for the prevention of loss of fishes through power tunnels, pumping plants, or diversion canals.

c. The state fish and game departments concerned be notified of water shut-offs in sufficient time to allow fish to be salvaged from affected stream sections.

d. Provision be made for the possible development of unaffected as well as affected streams so that anticipated losses to fish and wildlife may be mitigated.

e. Grazing by livestock be prohibited or controlled along the reservoir margins and about project works to permit vegetative cover to become established.

f. Waste areas, such as gullies and seeps, be planted and maintained for the benefit of wildlife to offset losses in wildlife habitat occasioned by project construction.

g. Project plans include provisions for the control of domestic and industrial pollution in both the reservoirs and streams of the project areas in accordance with

good management practices as well as established state and Federal laws.

h. Suitable lands within the flood pools be devoted to waterfowl food plantings and administered by an appropriate conservation agency.

i. Migratory bird refuges, fish hatcheries, or other management areas and facilities be established, where conditions warrant, to enhance wildlife propagation based upon detailed operation and maintenance plans developed by the Fish and Wildlife Service and the state or states concerned.

John C. Gatlin

John C. Gatlin,
Regional Director

PUBLIC HEALTH SERVICE

The Colorado River Storage Project and participating projects would consist of a combination of dams, reservoirs, power plants, and other appurtenance structures on the Upper Colorado River and its principal tributaries. The project would provide a means for the full development of the water resources and long time regulatory storage needed to permit states of the Upper Basin to meet their flow obligations at Lee Ferry, as defined by the Colorado River Compact, and still utilize their apportioned share of water. Lee Ferry, in northern Arizona, is the dividing point on the river between the Upper and Lower Colorado River Basins. During periods of low stream flow, the states would release storage water to meet the Lee Ferry flow obligation and in exchange they would divert upstream flow for use in the Upper Basin. The project would provide some storage water for direct use in the Upper Basin. In addition, the project would control sediment, abate floods, facilitate recreational development, and aid in fish and wild life conservation. It also would permit production of a substantial amount of the electric energy needed in the Upper Basin and adjacent areas.

All projects authorized subsequent to approval of the Upper Colorado River Basin Compact that would consume water of the Upper Colorado River system are considered to be dependent on the storage project for an assured water supply. Such projects have been designated as dependent projects. Benefits from irrigation, municipal, industrial, and related uses in the Upper Basin would be realized only with the construction of dependent projects. In this respect, the importance of the dependent projects is illustrated by the fact that the Central Utah Project, one of the major projects in this category, provides for 47,100 acre-feet of water annually for municipal, industrial, and related uses.

Construction Phase of Project

Public health services in the Upper Colorado River Basin are limited and the State and local health units are not adequately staffed in most cases to cope with local public health problems. The large construction program that will be required during the development stage will be located in rural and isolated areas. The influx of construction workers into areas without proper facilities to care for their needs or to provide for their families may create acute public health problems involving proper medical care and the provision of adequate sanitary facilities. In some cases, the construction work will be carried on in relatively remote areas and accommodations will have to be provided for the influx of workers and their families. In most cases, temporary camps will be provided for construction workers and facilities of a

more permanent nature will be provided for Bureau of Reclamation employees. Problems which may be encountered will include adequate housing, development of safe and ample water supplies, proper sewage disposal, adequate garbage and refuse disposal, insect and rodent control, proper food handling facilities and their control, safe sources of milk and meat supplies, and adequate medical care. Sanitary surveys of proposed construction camps by representatives of the State health departments or Public Health Service would be of considerable value in revealing public health problems that may be encountered during the construction phase of the projects. Plans of proposed sanitary installations should be forwarded to the respective State health departments for approval prior to construction so that the sanitary facilities to be provided will meet the requirements of the State health departments.

Some of the proposed impoundments will flood areas occupied by rural communities. In the relocation of these communities, precautions should be taken to remove or dispose of all wastes in accordance with the requirements of the local health authorities prior to the flooding of these areas in order to eliminate all sources of pollution. In connection with the relocation of these communities, proper sanitary facilities should be provided for each community, including a water supply system with a safe and adequate source of supply, proper sewage disposal and treatment, and provisions for adequate garbage and refuse disposal.

In connection with industrial health hazards that may be encountered on construction projects, provision should be made for the prevention of health hazards and accidents and the emergency treatment of injuries.

Proposed Recreational Development

The impoundments that will be developed will provide opportunities for the development of recreational areas on the adjoining watersheds. Most of these areas will be accessible to the public over highways that will be provided during the construction stage of development. Under these conditions, the areas that provide opportunities for fishing, boating, bathing, hunting, and hiking may be developed for recreational purposes. The areas that are of unusual scenic interest may also be considered for development.

The development of recreational areas in the vicinity of proposted impoundments may create public health problems if local sanitary requirements are not enforced. In addition to the possible effects of these installations on the use of the impounded waters for domestic water supplies at recreational areas or for irrigation purposes, the problem of providing adequate and safe sanitary facilities for the public at recreational areas is important from a public health standpoint. These problems include a safe and ample water supply, proper sewage disposal, adequate garbage and refuse disposal, insect and rodent control, proper food handling facilities, and safe sources of milk supply. Proper

design, construction, operation, and maintenance of resorts, tourist courts, private cabins, fishing camps, and boating and bathing facilities at proposed recreational areas are essential both for the protection of visitors and for the maximum benefit of subsequent water users. Sanitary requirements recommended by the State health departments or the Public Health Service should be adopted and enforced to solve the public health problems to be encountered.

Stream Pollution Problems

The Upper Colorado River Drainage Basin is sparsely populated and according to the 1940 census, 286,450 people were residing in the basin in 1940. The average density was 2.6 persons per square mile, compared with the national average of 44.2 persons per square mile. Grand Junction, Colorado; Rock Springs, Wyoming; Durango, Colorado; Price, Utah; Montrose, Colorado; and Delta, Colorado, are the six largest towns in the upper drainage basin, with a combined 1950 population of 47,600. The population in these communities ranges from 14,454 to 4,077 for Grand Junction and Delta, Colorado, the largest and smallest towns in this group.

Agriculture, particularly livestock raising, and mining are the principal industries of the upper drainage basin. The processing of agricultural products on a small scale is practically the only manufacturing undertaken in the upper drainage basin. Three factories are available for the processing of fruits and vegetables, and two for the processing of sugar beets and the refining of sugar.

The upper drainage basin is the leading domestic source of vanadium uranium, molybdenum, and radium ore. Zinc, lead, silver, and gold are commercially important. Large coal fields in the upper drainage basin are being extensively worked. About 15 million tons of coal were mined in 1943. Oil and gas are produced in the San Juan River Basin, the Uinta Basin, and in northwestern Colorado. Several producing fields have been developed recently and widespread exploration is continuing. Pilot plants are being operated to determine the best methods of extracting oil from shale.

Under conditions that prevail in the Colorado River Basin at this time, stream pollution problems are considered of minor importance with the exception of a few problems of a local nature. This picture may change materially under expanded industrial development. Although untreated domestic and industrial wastes are discharged into the streams in the Colorado River Basin, the pollution problems that are encountered are confined to local areas due to the limited volume of wastes in proportion to the water available for dilution purposes. Adequate treatment of these wastes prior to disposal is considered essential when the untreated wastes are detrimental to the subsequent use of water below points of pollution.

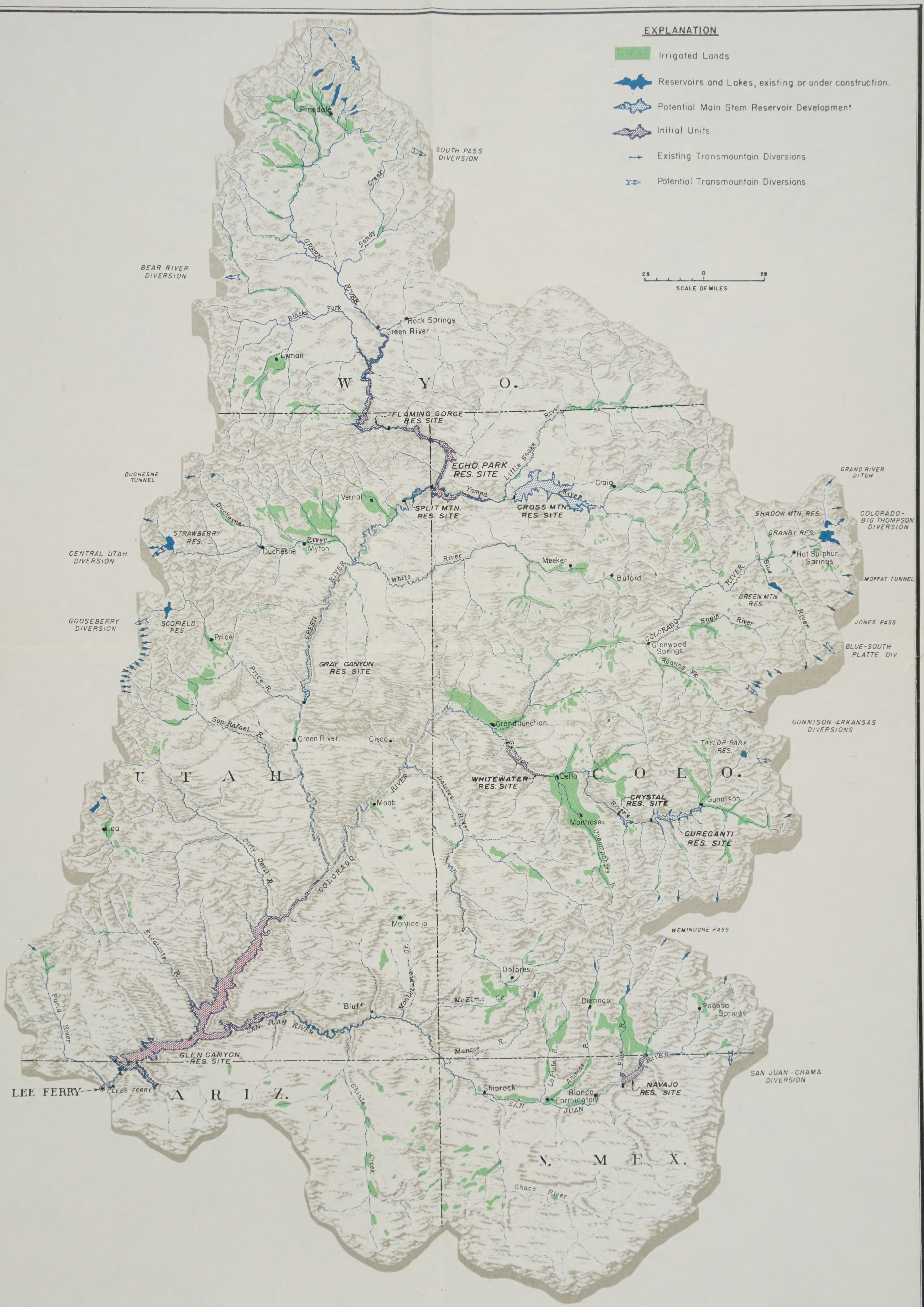
PUBLIC HEALTH SERVICE

Large scale industrial development in the Colorado River Basin may alter the problem of stream pollution to a considerable extent. The industries that may be involved in future development and expansion include: (1) processing of oil and oil products from vast reserves of oil shale, (2) manufacture of wood pulp and paper, (3) development of major oil fields, (4) further expansion of mining, and (5) processing of food and meat products. Untreated wastes from some of these developments may be responsible for pollution below points of disposal which may be deterimental to the quality of water to be used for irrigation and domestic purposes, development of recreational areas, and the propagation of fish and wild life. Most of these problems can be solved by the State health authorities in requiring adequate treatment of these wastes and by the cooperation of industry in providing treatment facilities. However, where these wastes will not respond to conventional or known methods of treatment, studies and investigations should be made by industry and the State health authorities in order to solve these problems. The cooperation of all interested parties is considered essential in order to eliminate existing and new sources of water pollution.

Natural purification that will take place in the proposed impoundments by means of prolonged storage, sedimentation, aeration, and biological changes should improve the physical and bacteriological quality of the water to a marked degree. The greater part of the sediment and soil pollution that will enter all impoundments will be removed or transformed into inert material by the processes referred to, thus providing water of desirable quality from a physical and bacteriological standpoint for various purposes including irrigation, domestic purposes, fish and wild life development, and recreation. These conditions will prevail if adequate treatment is provided for all domestic and industrial wastes responsible for stream pollution.

Mosquito Control

The development of the Colorado River Storage Project and participating projects may increase the population of mosquito vectors of certain diseases endemic within the boundaries of the project. These increases will probably not be significant over the whole project area. However, unless proper considerations are included in the project, it is believed that in certain locations these increases will be of considerable importance. Determinations of existing conditions relative to mosquito species and densities are necessary for proper evaluation of future developments that may grow out of the project. Investigations for such purposes should be made by public health authorities and completed in sufficient time to permit action which will tend to minimize mosquito production where such is deemed important to public health.


EXPLANATION
Irrigated Lands
Reservoirs and Lakes, existing or under construction.
Potential Main Stem Reservoir Development
Initial Units
Existing Transmountain Diversions
Potential Transmountain Diversions
25 0 25
SCALE OF MILES
Pinedale
SOUTH PASS DIVERSION
Sandy Creek
GREEN RIVER
BEAR RIVER DIVERSION
Blacks Fork
Rock Springs
Green River
Lyman
W Y O.
FLAMING GORGE RES. SITE
Little Snake River
ECHO PARK RES. SITE
DUCHESNE TUNNEL
Vernal
Yampa River
Craig
SPLIT MTN. RES. SITE
CROSS MTN. RES. SITE
Duchesne River
STRAWBERRY RES.
Duchesne
Myton
CENTRAL UTAH DIVERSION
White River
Meeker
Buford
GRAND RIVER DITCH
SHADOW MTN. RES.
GRANBY RES.
COLORADO-BIG THOMPSON DIVERSION
Hot Sulphur Springs
MOFFAT TUNNEL
Blue River
GREEN MTN RES.
COLORADO RIVER
Eagle River
JONES PASS
GOOSEBERRY DIVERSION
SCOFIELD RES.
Price
GREEN
GRAY CANYON RES. SITE
Glenwood Springs
Roaring Fk.
BLUE-SOUTH PLATTE DIV.
Price R.
San Rafael R.
Green River
Cisco
Grand Junction
GUNNISON-ARKANSAS DIVERSIONS
TAYLOR PARK RES.
Gunnison
U T A H
WHITEWATER RES. SITE
Delta
C O L O.
CRYSTAL RES. SITE
Gunnison River
Moab
Dolores River
Montrose
CURECANTI RES. SITE
Loa
Dirty Devil R.
Uncompahgre R.
COLORADO
Monticello
WEMINUCHE PASS
Escalante R.
Dolores
Paria River
Montezuma Cr.
McElmo Cr.
Durango
Pagosa Springs
Bluff
SAN JUAN RIVER
Mancos R.
La Plata R.
Animas R.
Pine R.
RIVER
GLEN CANYON RES. SITE
SAN JUAN-CHAMA DIVERSION
LEE FERRY
LEES FERRY
A R I Z.
Shiprock
Blanco
Farmington
NAVAJO RES. SITE
SAN JUAN
Chinle Creek
N. M E X.
Chaco River

UPPER COLORADO RIVER BASIN

REVISED: 7/50

UBANCO-S.L.C.,U.-1M- 12-50

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Dave Dickman
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SITES DISCUSSED IN COLO. RIVER STORAGE PROJECT & PARTICIPATING PROJECTS BUR of REC REPORT

Site Name	Hydrologic Unit No.	St.	T.	R.	Meridian	Quadrangle	~~Reasons~~ PAGE
WHITEWATER DAM	14020005-3 & 4	CO	2S 12S	1E 99W	UTE 6th	WHITEWATER	D13-18, H3-7, H11 4-7, 21, B18-19, B45-50, B54, B64, B80 POTENTIAL
CROSS MTN DAM		CO					D36-37, H3-11, H13 4-5, 7, B18, B22-25, B48-50, B54, B64, B80 "
(COTTON WOOD DAM) BLUE MESA DAM		CO					" 4, B18, B27, B54.
ECHO PARK DAM		CO					B80, D37-47, H3-11 4-7, 21, B17, B19, B29-32, B42-43, B48-50, B54, B64
ASHLEY DAM		UT					" 4, B17, B33, B54
GLEN CYN DAM		AZ					C4, D7-D13, H3-8, 4-7, 21, B17, B20, B35-37, B48-50, B54, B64, B80 EXISTING
(RATTLESNAKE) GRAY CYN DAM		UT					D18-22, H3-7, H13 4-5, 7, B17, B20, B38-40, B48-50, B54, B64, B80 POTENTIAL
NAVAJO DAM		NM					C5, D22-25, H3-7, H11, G19 " 4-7, 21, B18-19, B40-42, B48-50, B54, B64, B80
CRYSTAL DAM		CO					D31-34, H3-7 " 4-7, B18, B25-27, B48-50, B54, B64, B80
(BLUE MESA) CURECANTI RES		CO					D25-31, H3-7, H14 " 4-5, 7, B25, B27-29, B48-50, B64, B80
SPLIT MTN. DAM		UT					H3-11, H13 " 4-7, B17, B42-45, B48-50, B54, B64, B80, D37-47
BIG SANDY DAM		WY					12-13, 21 EXISTING
(ASHLEY) FLAMING GORGE DAM		UT					D34-36, H3-11 5-7, 21, B19-20, B33-35, B48-50, B64, B80 EXISTING
SPRING CRK "B" DAM		CO					13 POTENTIAL
STRAWBERRY RES		UT?					14, G17 "
JOES VALLEY RES		UT					14, G18 "
LEMON DAM		CO					14, G18 "
SOLDIER CRK DAM		UT?					14, G17 "
HAMMOND DIV.		NM					14-15 "
LaBARGE DIV.		WY					15 "
BRIDGER RES		WY					15, G20 "
VALLECITO RES		CO NM					15, G20 "
RIFLE GAP RES		CO					16 EXISTING
CRAWFORD DAM		CO					16
SMITH FORK DIV.		CO					16
HOOVER DAM							B8 EXISTING
GRAND VALLEY DIV		CO					B15 "

DEC, 1950

SITES DISCUSSED IN COLO RIVER STORAGE PROJECT & PARTICIPATING PROJECTS BUR. of REC REPORT

Site Name	Hydrologic Unit No.	St.	T.	R.	Meridian	Quadrangle	~~Reasons~~ PAGE
CROSS MTN PP		CO					B23
GLEN CYN PP		AZ					B36 EXISTING
DESOLATION DAM		UT					B50
DEWEY DAM							B51 POTENTIAL
(BLUFF) CHINLE DAM		UT					B51 "
BLUE MTN DAM		CO					B51 "
GOOSENECK DAM							B51 "
SLICK HORN DAM							B51 "
SHIPROCK PROJECT		NM					G5-6
NAVAJO ANIMAS-LAPLATA PROJECT		NM					G6 POTENTIAL
UINTAH & OURAY PROJECT		UT					G7
JICARILLA RESERVATION PROJECT		NM					G7
SOUTHERN UTE & UTE MTN RESERVATIONS		CO					G8
SOUTHERN UTE							G8
UTE MTN							G8
BIG SANDY RES		WY					G15
SPRING CRK RES		CO					G16
MONKS HOLLOW RES		UT					G17
MONA RES		UT					G17
SEEDSKADEE PROJECT		WY					G21
LaBARGE PROJECT		WY					G21
SILT PROJECT		CO					G22
SMITH FORK PROJECT		CO					G22